COMMANDER D. WILSON-BARKER, R.N.R.
(*President of the Royal Meteorological Society* 1903-1904).

QUARTERLY JOURNAL

OF THE

ROYAL

METEOROLOGICAL SOCIETY.

EDITED BY

A COMMITTEE OF THE COUNCIL.

VOL. XXXI.—1905.

LONDON:
EDWARD STANFORD, 12, 13 & 14 LONG ACRE, W.C.
1905.

CONTENTS.

PLATES.

ERRATUM.

Page 52, Fifth line from the bottom. *For* 0·4 in. *read* ·04 in.

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

VOL. XXXI.] JANUARY 1905 [No. 133

METEOROLOGICAL OBSERVING IN THE ANTARCTIC REGIONS.

BY LIEUT. CHARLES W. R. ROYDS, R.N., F.R.G.S.

(1st Lieut. National Antarctic vessel, *Discovery*.)

[An Address delivered to the Royal Meteorological Society, November 16, 1904.]

BEFORE commencing my remarks, I should like to explain that on account of the observations not being worked out, I am unable to give a detailed account of the actual conditions of the weather in the Antarctic regions. I should also like to say that I am not a meteorologist.

My work during the Expedition has been purely that of organising and looking after the taking of the observations. I will therefore try and explain how this was done, giving you some idea as to the position and method of the instruments used.

There is one thing that has struck me ever since we arrived in our winter quarters and started the observatory down there, and that is that it is most essential and most important that the man in charge of the work should know clearly what he is doing, and what is expected by the authorities at home should be done. In my own case, I most sincerely regret that I did not go thoroughly into the work before we left England. There were two reasons that stopped me: first, that being the Executive Officer, I had my hands full preparing the other parts of the Expedition; and, secondly, I had never really thought of what an important part in the final results this work of meteorology took. It is true that for a week in January I went up to the observatory on Ben Nevis, and saw to some extent the difficulties in observing up there in strong gales and those caused by the fog crystals; but even then it never struck me how much it really affected me in the work that was to be done, consequently our instruments came on board and were at once stowed below until required. I left England with no fixed idea as to how the observations were to be

taken, ignorant, I am sorry to say, of the workings of some of the instruments, and entirely ignorant of what was expected to be done by the authorities at home. I think you will all agree with me that that is not the best way of starting on an expedition of which the results of the observations are most important.

In looking over my notes, written whilst we were down there, I see the very first remark is as follows:—"Everything that can be fitted and the instruments to be used should be set up before the ship leaves the home port, as it is hardly fair to trust to the mechanical skill available when, with only a little forethought, everything could be seen to beforehand." Since writing that my opinion on that subject has not changed a bit, but rather do I add to it by saying that all the observers, if possible, or at

FIG. 1.—General View of Winter Quarters.

any rate the man who carries the title of Meteorologist to the Expedition, should be absolutely acquainted with the instruments he is going to use.

I will pass over the time from the ship leaving England to the time of our arrival in winter quarters, and simply say that the usual observations at sea were taken.

On February 8, 1902, we arrived at our winter quarters. As soon as the water in the bay was frozen, the meteorological screen was set up on the ice, and on April 17, 1902, observations were started from, to all intents and purposes, a "land station" in latitude 77° 50′ S., and continued until February 15, 1904, when the ice broke up and allowed the ship to go free.

Before speaking about the instruments, I ought to say something about the locality. The ship was in a small bay of about a ¼-mile in depth; all round from north-north-west through east to south-east there was land rising quickly to some height. In the north-north-west

the hills were 400 ft. high, and these extended to north-east, and then a hill of 1000 ft. in the east and one of 700 ft. in the south-east. Between the east and south-east was a deep gully, or gap as we call it, which opened out on to the great ice barrier. From south-east through south and west to north-west we were entirely open, except for land 20 to 50 miles away. From north-west back to south-west was the Albert Range, rising to peaks of 15,000 ft., and to the south were some islands 3000 ft., and land rising to 8000 ft.

The screen being set up, observations were taken every two hours, the day observations from 8 A.M. to 10 P.M. being taken by myself, and the night observations being divided between the eleven officers, each officer taking a night. The two-hourly observations taken were, the barometer and attached thermometer, the dry- and wet-bulb thermometers, and the spirit minimum, the outside thermometer (of which I will explain more later), the Assmann aspirator, force and direction of wind by Beaufort's scale, and the velocity by the Robinson and a small Dines anemometers, the weather, direction and movements of upper and lower clouds, and general remarks. At 8 A.M. and 8 P.M., in addition, the maximum thermometer was read; at 10 A.M. Dines recording sheet was shifted; at noon two other barometers were read for comparison, and a sunshine-recorder card was shifted, and the evaporation was taken by weighing two dishes of ice (of which I will speak later); and at 8 P.M. the black- and bright-bulb thermometers were read. On Monday mornings, at 10 A.M., the records of two, sometimes three, barographs were changed, two and sometimes three thermographs, and two hydrographs. In addition, sea, earth, and snow temperatures, at various depths, the increased thickness of ice, and snowfall, were recorded. Observations of the movement of Mount Erebus smoke were recorded whenever seen, and every day—sometimes three and four times a day—observations were taken at a thermometer off Cape Armitage, 1½ mile from the ship, simultaneously with the screen observations. For a short time a thermometer was placed on the summit of Crater Hill, 1000 ft. high, but these observations were discontinued.

During the latter part of our stay observations for ozone were taken with very interesting results. Also in our "constitutionals" we used to take a thermometer and note the temperatures at various places in the locality, either up the hills or along on the ice; but owing to the number of accidents to these thermometers, we were unable to carry this out to any large extent.

Observations of the aneroid, and in some parties the hypsometer, the dry bulb and minimum readings of the thermometer, weather, clouds, general remarks on snow surface and snow temperatures, were always taken by the sledge parties; and as many as six different parties have been observing more or less at the same time as the observations taken at the screen.

I will now take the instruments separately, and in some way hope to show you the difficulties of observing in those regions.

The barometer, a Kew pattern instrument, was hung in the magnetic house on board the ship, that being the only position I could find where it would remain untouched. The disadvantage to its position was the exceedingly low temperatures, the attached thermometer often going

down to $-14°$, but it was marked to $-40°$. The variation in the temperature of the room was occasioned by the door being left open or being unable to be shut on account of drift. As an instrument of warning we lost all faith in it, the gales coming on without an apparent quick fall or rise of any great extent.

We will now turn to the thermometers, taking the dry bulb first. This was an ordinary mercurial thermometer, graduated down to $-45°$, and was placed in the screen which faced about north-east and south-west. I see in my notes that I have the following remark :—"I cannot understand why spirit thermometers were not supplied for ordinary use." Since returning I find that I should have used the spirit thermometers with the index in them, of which a good number were supplied, but these I only used as minimums.

We will now take the wet bulb. Throughout the winter of 1902 the observations of the wet bulb were by no means satisfactory, as seldom did the dry and wet thermometers differ in their readings; and if they did it was generally that the wet bulb showed a higher reading. I account for this for two reasons. Firstly, the coating of ice which was constantly kept on the bulb was too thick, and so prevented the effect of the evaporation from effecting the mercury; and, secondly, the fact of having muslin and ice over the bulb did not allow a quick change of temperature to be felt by the mercury, and so should the temperature fall quickly the dry bulb would show lower than the wet, but should the temperature rise quickly the wet bulb would show lower than the proper difference reading should be. During our second year the results were very much more satisfactory, as I kept only a small amount of ice on the thinnest bit of muslin, shifting the muslin every Monday morning, so that accumulation of ice could not take place.

As I am on the subject of evaporation I might mention an experiment which I carried out. Two open shallow dishes, 3 ins. by 4 ins., filled with water and allowed to freeze, were placed on the top of the meteorological screen. These were weighed before being placed in the dishes, and 24 hours later were again weighed—the difference in weights being the evaporation in drachms. Whether or not the authorities will be able to make anything out of the experiment I am not in a position to say; but I sincerely hope so, as it was no pleasing job weighing the dishes, as on account of the small weights used for that purpose one could not handle the forceps with mits on, and consequently it meant frost-bitten fingers very often.

The next instrument is the minimum thermometer. This was placed in the screen and read every two hours, and reset. To commence with, I had a great deal of trouble with these instruments, the columns so very often breaking, and several thermometers were broken in the vain attempts to restore them to working order. In comparing the spirit minimum with the mercurial thermometer at the present time reading, the former very often showed a difference of $1\frac{1}{2}°$ below. Whether this is due to the fact that the mercury registers quicker or slower than the spirit I would not like to say; as far as I could see it was not due to any defect in the spirit minimum, and I never saw any escape of spirit to the top of the instrument which might have accounted for the difference.

Whilst talking about the minimums, I might again say that for a

time during the first winter one of these instruments was placed on the summit of Crater Hill, and one observation was taken daily. There was also another placed about 1½ miles from the ship to the south, and this also was read daily, and sometimes three and four times a day, as it was used by the officers as an excuse for a walk. The difference between these and the simultaneous observation at the screen was very great. For example, on August 15, 1902, the noon observation at the screen was $-20°$, and the wind was light Easterly air. At the high-level station the temperature was $-26°$, and out at Cape Armitage it was $-37°·5$. Another example with even bigger differences. On August 10, 1902, the screen temperature was $-35°$, also light Easterly airs; high-level station, $-37°$; and Cape Armitage, $-50°$. The lowest temperature recorded at the screen during our stay in the winter quarters was $-59°·5$, the corresponding minimum at Cape Armitage being $-64°·6$ for that day, August 20, 1903. The coldest temperature recorded at Cape Armitage was at noon, May 16, 1903, when it showed $-67°·7$, or nearly 100° of frost. Our mercurial thermometers were not often frozen, the longest spell being for 56 hours, during which time the mercury remained in the bulb. During these times, and whenever the temperature was below $-40°$, observations were taken from the end of the column, as well as the minimum from the spirit minimum thermometer.

I might mention that the highest temperature for the first year was $+39°$, on December 26, 1902, and it is a coincidence that in the second year (1903) the highest temperature was $+42°$ on the same day, December 26.

Of the other thermometers used, there was one placed on a stand outside the screen, and in the open air. During the winter months, that is, from April to August, when the sun is below the horizon, this outside thermometer nearly always showed less than the inside thermometer. Later on, after the sun had taken effect, this nearly always showed higher and fell below again during the night; and when the sun was above the horizon the whole day, the outside thermometer nearly always showed a higher temperature to that inside the screen.

Before leaving the thermometers, I should like to say a good word for Assmann's aspirator. It is true we used to call it the "Ex-aspirator," as it was placed in the open air, and one had to read it facing the wind on account of the heat from the body affecting the reading. The graduations were minute, and one's eyes being either filled with drift or tears from the drifting snow or cutting wind, it was most difficult to read. Then again, the instrument had to be made to work by means of a key, and this necessitated removal of one's mits, and consequently frost-bitten fingers; anyhow, for all the disadvantages, many of which could be entirely got over, the observations taken from this instrument are, in my opinion, truer readings of the actual air temperature than those given by the thermometers in the screen. Other thermometers were used, such as earth, snow, and sea thermometers, but I am afraid time will not permit me to speak about them. The only other ones I will touch on are those for solar radiation, which are the black and bright bulbs *in vacuo.* I regret very much that these instruments were not graduated down to $-40°$ or below, instead of only to $+10°$, as I cannot help thinking that observations taken throughout the winter

with these instruments would have been most interesting, and may have thrown some light on to the difference of temperature between Cape Armitage and the screen thermometers. Our highest black bulb reading in 1902 was 154° on December 21st, and during 1903 it went up to 151° on December 8th.

We will now leave thermometers and turn to the instruments used to measure the force of the wind. We will take first of all the eye observations by Beaufort's scale. Now I think all will agree with me that the force of the wind as recorded in the mind of any human being will be in proportion to his own personal comfort, that is to say, if it is blowing very fresh, for example, but it is nice sunshine, probably

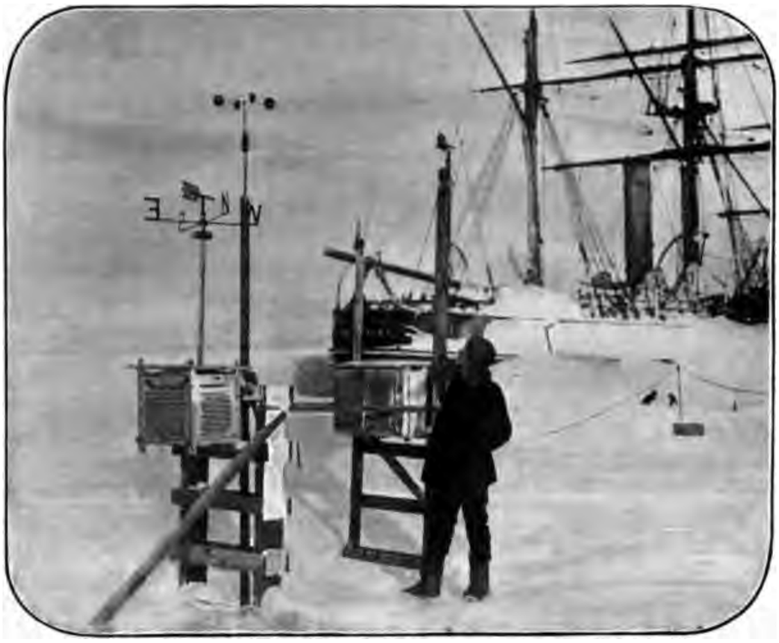


FIG. 2.—Meteorological Station.

one might register the wind as 5 to 6. Now, let it be raining or snowing, or a dark night, and the observer has the toothache or rheumatism, or has to get up in the middle of his dinner, or just when he is enjoying a pipe in a nice warm room, and then see if that same observer will register the wind at 5 to 6. So that probably for the first few months of our stay down south the wind was registered too high.

But besides eye observations we had several mechanical instruments for recording more or less the same thing. There was first the Robinson anemometer. During the whole time this instrument has been working with hardly a stop; but I must confess that this was due entirely to the mechanical skill of Mr. Skelton, as without him the records would have been stopped some few months after the instrument was started, solely on account of there being no spare arms or cups supplied with the

instrument. I have never understood why this was not done, as the experience of the Southern Cross Expedition plainly showed that the gales were very heavy, and they themselves had to discontinue observations by the Robinson on account of their instrument being broken in a gale, and having no spare ones or parts of one. Another thing to be remembered about this instrument for future work out there is the fact that the case is not drift-tight, and consequently in the blizzards the inside gets choked with drift, hiding the dial and stopping the easy working of the instrument. To prevent this I placed gummed paper all round the glass case, which worked satisfactorily. I should be inclined to suggest a larger instrument being used, but if the accuracy of the instruments is about the same, the question of a large or small instrument becomes merely a matter of taste. Snow when drifting always collects in the cups, which must to a certain extent affect the results; at every two hours the cups were cleared if necessary.

We now come to the Dines two instruments; the one we call small Dines being out in the screen, and the large recording Dines which was set up on board. The same difficulties occur in both, as each instrument is fitted with pipes, and a vane connected with them, the latter having an open hole in the head. Now this hole in the head was invariably choked in heavy blizzards, and necessitated the observer clearing it at every observation. Out on the screen this was more or less easy, but on board the head was situated in the mizen crosstrees, and it was no pleasing job climbing aloft in the howling blizzard to clear the head, which one knew would be as bad again at the next observation. We had also great difficulty with the liquid for the self-recording Dines. This was a mixture of pure spirit and glycerine. Now should there be a calm and low temperature, *i.e.* below $-40°$, the spirit and the glycerine used to separate, the spirit rising to the surface, and the bottom of the float was in a thick liquid resembling condensed milk. When the instrument was first set up, and this occurred, I took it to pieces, and found a large amount of ice, which I presumed was the water frozen, which had been mixed with the glycerine, and so I removed it. As you can imagine the separation of the liquid stopped the correct working of the instrument. Another difficulty was the fact of one's breath collecting on the piston-rod, and forming a coating of ice which effectively stopped the working of the float. Throughout the whole time in the low temperatures I had the greatest difficulty with the clock, as it invariably stopped. Whether this was due to the fact that it was not compensated sufficiently I should not like to say. The whole fact summed up is this, that in those blizzards, which really are not uncommon at all times of the year, but more generally during the winter, it is nearly impossible to keep any of the self-recording instruments at work.

It is a very difficult thing to any one who has not experienced a blizzard to know what happens. The air is entirely filled with driving snow, which strikes you just like a sand blast. You cannot face it, but have to stumble on to wherever you may be going with your head down and arms protecting your face, and even could you face it you are not able to see an inch all round you. I will give you an instance of how blinding they are. Whilst preparing for winter on our arrival in the Bay, and after the sea had frozen over, posts connected with ropes were

laid to every place where it was necessary to go every day—that is, to the magnetic huts and living huts, and to the meteorological screen. It was during the latter part of the first winter that what might have been a serious affair happened. You may have heard that we had at times concerts, theatricals, and at one time a nigger troupe, to liven things up. Now it was no good rehearsing these things in the ship, as every one would know exactly what was going to be done, and the jokes to be made, consequently it meant the performers going over to the huts for the rehearsals, and, as in this Palace of Varieties there was invariably a temperature of $-20°$ and below during the time we were rehearsing, it was no great pleasure playing the piano. It was on one of these occasions that I had taken the party across to the hut to rehearse the nigger troupe, and it was blowing a hard blizzard with exceedingly low temperatures. On arrival at the hut we found two officers—Mr. Skelton and Mr. Bernachi—taking pendulum observations, but they left before we started our rehearsal. We finished in about one and a half hours, and then started back to the ship. It was then blowing stronger than ever, and I had cautioned all the men to keep together and not to let go the rope which led back to the ship. We had got about half way across when I heard a shout, and knew that as it was none of my party some one must be adrift from the ship. We opened out, holding each other's hands, and found Mr. Skelton and Mr. Bernachi absolutely lost, and they had been wandering about for one and a half hours, unable to find out their whereabouts. Both were more or less badly frost-bitten about the face, and were exceedingly glad to have been found. One could quote many instances of the like nature, all pointing to how absolutely helpless one is in a blizzard unless you know exactly where you are.

During these blizzards the ship gets more or less buried, and everything else besides. After one or two of these it is always necessary to lift and move the meteorological screen, as it is invariably buried. You can imagine how impossible it is to measure the snowfall under these conditions. In fact, to tell the truth, it is always a matter of some surprise when, after the blizzard was over, one was even able to find the snow-gauge, which was completely buried under as much as three and four feet of snow.

The great peculiarity of these blizzards was the invariable rise of temperature. They always came from the South and South-west, and once the wind got back to the South-east or East the temperature always fell again. Great fluctuations in the thermograph curve always gave us some warning of an approaching blizzard. To get caught in one of these on a sledge journey was no joke, and once I was five days in a tent unable to do a thing. At another time, in the same spot, Dr. Wilson was kept for nine days; in fact, it was an uncommon thing for a party away sledging not to be laid up for one or more days.

It is these blizzards that make the work of observing so hard and stop the instruments. All the self-recording instruments suffer badly, as the drift gets inside the boxes and entirely chokes them, drying up the ink in the pen, smudging the ink on the paper, and forming round and over the working parts, completely stopping their working. Even in fine weather it is no joy shifting the sheets of these recording instruments, as it necessitates your working without mits, and in a wind it is a ghastly

and most painful job. You cannot take the instrument inside the ship, otherwise you get condensation on it, not to mention the fact of having a difference between it and the standard instrument at the time of setting —so one has only to grin and bear it. Many is the time that the makers of those instruments have been blessed for their invention by myself and all who had any dealings with them down there, as it is real agony playing with them at times.

The wind about the locality was very peculiar. It would be blowing hard in the bay, where the ship was, from the East, and on getting out to Cape Armitage, only one and a half miles away, one nearly always got it calm. Again, these strong Easterly winds, which are the prevailing winds, are not felt at the other side of the Strait. On one occasion a

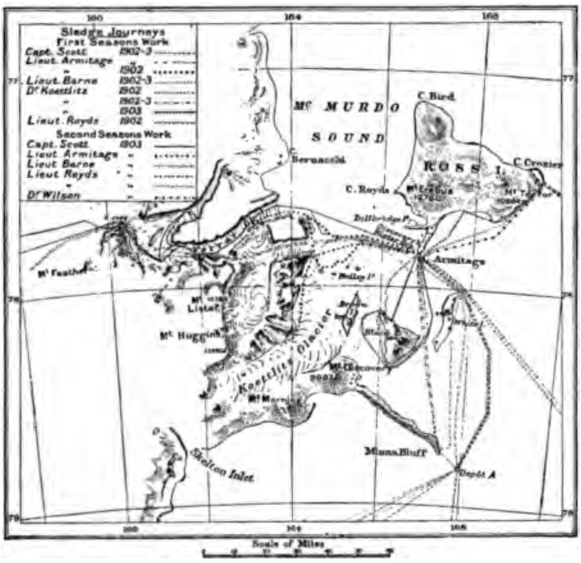


Fig. 3.

party for the Western Mountains started off with a strong Easterly wind, and with sail set made an excellent start, but after about ten miles across the ice they lost the wind altogether, although it still remained blowing hard at the ship.

Our heaviest gale was on July 19, 1902, between the hours of 4 P.M. and 8 P.M. of the next day. From 10 P.M. to 10 A.M. the Robinson anemometer gave an hourly velocity of 85 miles. In the latter part of the gale the temperature had risen to + 15°, although it had been below - 20° the day before, and dropped again immediately the wind went to the East.

The wind on the sledge journeys is rather interesting. Throughout my journey to the South-east on the barrier surface we got a perpetual South-west wind; all the "Sastrugi"—those are the snow ridges caused by the wind—pointed to South-west, and to all appearances it is the prevailing wind. The party, on their journey up the glacier to the

Inland Ice-plateau behind the Western range, got continuous West-south-west winds, whilst at the ship they recorded continuous strong winds, but more or less from an Easterly direction.

Our second year's sledging season was considerably worse for sledging conditions than our first, and all the parties, on their return, complained of the incessant winds, which delay a sledge party most dreadfully. It was at Cape Crozier that a party always got strong gales, and personally I had a good deal of experience of that spot, having been there four different times. Across the Bay, between Cape Armitage and Terror Point, I never had any wind whatsoever, and neither is there any indication of anything stronger than light airs.

It was on my first journey, in March 1902, that I found the snow so soft and the dragging so heavy that I split up the party, sending the dogs and men back, and continued, with two other officers, to complete the journey. It was with the returning party that the only fatal accident happened throughout our stay in the Antarctic regions, they being caught in a blizzard on the hills which surrounded the ship, lost their way, and, arriving on an ice-slope, were precipitated down, one poor chap falling over the edge into the sea.

To return now to the instruments. There is about only one other instrument which I have not mentioned, and that is the sunshine-recorder. Now this is one of the instruments I particularly meant, of which I was ignorant of its working; anyhow, although quite the wrong way, I used to get the recording cards in and get the line burnt.

Before going South I certainly gathered from Ross's account that the sun seldom showed itself. This we find to be entirely wrong, as day after day we got most glorious clear skies and continual sunshine. You will see on the screen three cards of 24 hours' sunshine. This is rather unique, as, until our Expedition, no instrument was made to record the whole 24 hours. The effect of the sun was very marked on our faces; after the winter, when you turn yellow and various other colours from living in artificial light, you went away sledging, and were out in the sunshine for nine and ten hours every day, one's face turned absolutely brown and one's lips cracked; the skin also blistered, and in many cases one's face became swollen. I might mention here that very painful thing, snow blindness. Speaking for myself, I know of no worse torture, and one's eyes seem filled with red hot sand. For 48 hours I was totally blind, being led from the tent to the sledge and harnessed up, and when the next stop came for a meal, unharnessed and led back to the tent, observations and leadership being taken by others.

We have now spoken about the greater part of the observations, but there still remain the clouds. I must say that during our time spent in the Antarctic circle I have never seen such beautiful and striking examples of every sort of cloud. Whether it is that one doesn't stop to notice them in more civilised parts, or whether they are really more striking, I could not say. There are, of course, the dull days, which are by no means uncommon; at times the whole sky, horizon line and snow down to your feet, is one uniform colour, and if this occurs whilst you are sledging it is nearly impossible to proceed. That word "pallium" is a most expressive term for those overcast days. The Cirrus, Cirro-stratus, and Cirro-cumulus are at times really wonderful; and when

the sun is below the horizon, the colour thrown on the clouds, and in fact everything, is perfectly gorgeous. We had very striking examples of what we called "mother o' pearl" clouds, apparently at a very high altitude, and of the most exquisite colouring, and which really defy description.

Whenever a gale was coming on the high land invariably became banked with heavy masses of Cumulus, and peculiar clouds formed over the summits of the higher peaks. Over the open water around the foot of Erebus there were always heavy banks of Cumulus. I tried to take photographs of clouds, but never made any great success of them.

With regard to the precipitation, as I have remarked before, it was impossible to determine it during the blizzards. Throughout the winter months very little snow falls; but during the summer months we had very heavy falls of snow, sometimes small dry flakes, and at other times the more common English snowflake, large and damp. At times there was considerable precipitation during clear weather of most beautiful ice crystals; and whilst sledging the effects of the sun on these crystals was most dazzling. Throughout our stay inside the Antarctic circle we recorded no rain; only on one or two occasions did we get any large accumulation of fog crystals so common on Ben Nevis. I might mention that fogs are not nearly so prevalent as is supposed, unless we were lucky in not meeting them.

Of other phenomena the mirage is the most common, and at times is very considerable. Halos and coronæ are also very common, and we have seen some beautiful and complicated halos. The auroras were not uncommon, but from the accounts of some of the members of the Expedition who had also seen the aurora borealis, that is in the north, the aurora australis is not so highly coloured nor so brilliant; but all the same it is perfectly magnificent at times. I have not been able to see any connection between the weather and the aurora, although at times, before any strong gale, we seem to get an exceptionally bright display.

Early in the evening I spoke about the taking of observations of the direction of Erebus smoke. Now Mount Erebus is a mountain of 12,000 feet, and it was an unfortunate thing for us that we, in our bay, could not see the mountain from the ship, but had to walk out about 300 yards or so before we got it in view. Whenever anyone went out for a walk or was in sight of the mountain, they always on their return reported which way the smoke was going. The usual direction was to the north-east, pointing to an upper South-west current. We invariably expected wind if we saw the smoke going to the north-west, and were seldom disappointed. It was a most common thing to see the smoke going north-east at the same time you, on the level, were in a strong Easterly wind; and I have noticed detached clouds, only about 2000 ft. below the summit, passing quickly to the west, while the smoke was going in a steady stream to the north-east.

At times Erebus smoke rose quite rapidly some 3000 feet, and then broke away. On a few occasions during the dark months we observed a red glow on its summit, but there was no big eruption. You can understand what a very magnificent mountain this is, and so also is its sister Mount Terror of 10,000 feet. This is, to all intents and purposes, inactive, but I don't think any one of us would say that it was extinct.

On more than one occasion I have seen what looked remarkably like steam coming from the crater, and others have reported the same thing. I remember very well that it was on my first journey round this mountain that we distinctly saw steam, but never smoke; now, on the other hand, other people thought it was a small cloud or drift-snow, and we had a heated discussion. It was on this same journey that our party got our first low temperature, and it came as rather a shock to us as we were not prepared for any such cold. It was in March, and we had taken our fur suits to sleep in, instead of the fur bags which we always afterwards took. On our return, during the night we were camped, the temperature fell quickly. We knew that it was cold, as by no means in our power could we stop our teeth chattering or our bodies from continuous shivers.

FIG. 4.

The doctor, who was a hardy veteran of the north, suggested that he did not like the look of things at all; both Skelton and myself were quite inexperienced to cold, and did not quite know what we had let ourselves in for. It was Skelton who suggested going out to see what the temperature was, and it certainly did not improve matters when he came in and said it was -42° or 74° of frost. Anyhow it was no use feeling cold without making some effort to get warm, so Skelton lit the lamp and made us a cup of hot cocoa, after which we fell asleep, the temperature rising before we got under way in the morning.

I mention this to show you how impossible it is to gauge the temperature in those regions, as to get so low a temperature in March was extraordinary.

How many times has one been asked questions with reference to the cold—"Wasn't it too awful?"—and such like. Now it would be very

absurd for me to say that it was not cold, but this I do say, you really do not feel it unless there is a wind.

It would not be out of place to mention some of the clothing. The cold is such a dry cold, so different to what you get in England, and yet many say: 'I suppose you don't feel an English winter," but it is quite a mistake. It was not very often that we got strong winds with temperatures below $-40°$; but on occasions this did happen, and the observer dreaded the time when he had to go out and take the observations.

In the very low temperatures, *i.e.*, below $-50°$, there was always a mist hanging over the land, occasioned by the warm air rising from the tide cracks. Now tide cracks are the cracks all along the coast-line made by the rise and fall of the tide. Another rather peculiar thing was observed in these very low temperatures—one heard one's own breath freezing—if you turned your head in the direction of the light airs and breathed out you heard a distinct crackling as the breath flew back past your ears; but as this necessitated your ears being uncovered it was not tried too often.

Speaking of temperatures, I might say that the second year's season was much colder than the first. Whether this will be so when the means are worked out I do not know, but one can give reasons for it by the fact that there was more ice in the vicinity, and also that ice was much thicker than in the first year.

Before bringing my paper to a close, I should like to say a few words with reference to the thickness of ice and ice-pressure.

Much has been reported with regard to the enormous height of icebergs, instances being quoted of 500, 600, and even 1000 ft. Now the Great Ice Barrier is to a large extent the birthplace of the greater number of these bergs. On passing along its face we sounded continually, and obtained a more or less even depth of 400 fathoms. Now ice of this nature floats with about eight times as much of its area below the water as there is above; consequently a berg of 500 ft. would be drawing 4000 ft. or nearly 700 fathoms. So you can see that no berg of more than 300 ft. could float away from the Barrier. I would not go so far as to say that there are no bergs of these dimensions—more or less—as our region of exploration was so minute in comparison to the large area still unknown. With regard to the length of a berg I give no limit, the Barrier being over 400 miles long.

I must now thank you for your very kind attention, and only hope that I have been able to give you some idea of the work done in meteorology by the officers of the *Discovery* during their stay in the Antarctic regions.

Before the reading of the Paper the PRESIDENT (Capt. D. WILSON-BARKER) made the following introductory remarks:—

We have the pleasure of welcoming this evening Lieut. Royds of the *Discovery*, in whose charge the meteorological work of the Antarctic Expedition was placed. It is perhaps superfluous to remind you that the scientific exploration of the Antarctic regions was a long-wished-for and much-talked-of event, that was finally undertaken and successfully achieved mainly through the persistent energy of Sir Clements Markham, the able and learned President of the Royal Geographical Society. Years of strenuous effort on his part bore fruit at last in producing the necessary funds and the right men for the work.

Other countries have co-operated and have equipped kindred expeditions, so that when the vast mass of information accumulated has been sifted and arranged, we shall undoubtedly be in possession of much valuable scientific data. The meteorological work of the *Discovery* has been first rate. Mr. Royds will give us, this evening, an idea of the conditions in which the investigations and experiments were carried on. He has, of course, not had time to work out any detailed analysis of results obtained, but the circumstances of his labours have been unique in meteorological research. I take this opportunity of recalling the fact that one of our Fellows, Mr. R. C. Mossman, is at present in the South Orkney Islands, a voluntary exile in these Antarctic border lands, for the purpose of taking meteorological observations. Mr. Mossman accompanied Mr. Bruce in the Scotch Expedition to the Weddell Sea, and he remained in his present quarters to pursue his investigations.

The Argentine Government Meteorology.

The Argentine Government have resolved to continue the station at Scotia Bay for a third year, and thus for the first time in the history of Antarctic Exploration there will be a record of observations for three successive years from the same place. The new party consists of five men, four of whom have been in the employ of the Officina Meteorologica Argentina. The *Uruguay*, the vessel which is taking down the relief party, is, it may be remembered, the same vessel that effected the relief of the wrecked Nordenskjöld party in 1903.

Material is being taken out for a new house, 7 feet by 16 feet, and 7 feet high, for the magnetic variometers. Copeland Observatory, built by the Scottish Expedition, will be furnished with instruments for absolute determinations. It is hoped that it will be possible to obtain simultaneous observations from the two magnetometers—the Scottish one at present in use and the new Argentine instrument—while the *Uruguay* is in Scotia Bay.

The Argentine Republic has a magnificent set of both meteorological and magnetic instruments, which are to be installed this summer (1904-1905) at the Penguin Islands. Thus the islands in the South Atlantic are to be well supplied with magnetic and meteorological observations; Scotia Bay, South Orkneys, Penguin Islands, New Year's Island, being all equipped by the Argentine Republic. That country deserves the greatest credit for such splendid enterprise. Besides these, there is Cape Pembroke, Falkland Islands, recently equipped and inspected by Mr. W. S. Bruce in co-operation with the British Meteorological Office. Monsieur Charcot, of *Le Français*, is also carrying out at the present time observations on the west side of Graham Land. All these, in co-operation with the splendid meteorological system, at present under the control of Mr. W. G. Davis, of the "Oficina Meteorologica Argentina," over the whole of the Argentine Republic, form a unique series of observations in the history of meteorological and magnetical science.

Captain Larsen, who was master of the *Antarctic*, the vessel of the Swedish Antarctic Expedition, left Buenos Ayres in November for South Georgia with his whaling steamer *Fortuna*. The company under which he sails intends to make South Georgia a permanent station for the boiling down of whale blubber. Mr. W. G. Davis has taken advantage of this, and has supplied him with a complete set of meteorological instruments, both for self-registering and direct observations, to be set up at South Georgia, where it will now not be difficult to have them frequently inspected.—*Scottish Geographical Magazine*, January 1905.

(*See also pages* 38 *and* 74.)

DECREASE OF FOG IN LONDON DURING RECENT YEARS.

By FREDERICK J. BRODIE, F.R.Met.Soc.

[Read November 16, 1904.]

In a paper read before this Society in 1891,[1] some statistics were given which pointed unmistakably to a steady increase in the prevalence of fog in London throughout the two decades ending with 1890. In the 13 years which have since elapsed the tendency has been so strongly in the opposite direction that little apology is needed for bringing the subject once more before the notice of the Society. The figures quoted in the earlier paper, and those now presented, have all been derived from the same source, viz. the London records published in the *Daily Weather Report* of the Meteorological Office, and may therefore be regarded as strictly comparable. Throughout a considerable part of the period the entries in that publication have included weather observations made, not only at certain fixed hours in the day, but also at intermediate times, the latter being classed under the heading, "Weather in the past 24 hours." During the years 1876 to 1891, however, the particulars were given for three definite hours only, viz. 8 a.m., 2 p.m., and 6 p.m., and in order to make the fog record as complete as possible it was necessary for those years to consult the original records, in which the observations were set out in greater detail. It must, therefore, be understood that the figures quoted include all cases in which fog was observed at Brixton, the London station of the Meteorological Office, in addition to some few instances in which that locality escaped a visitation which affected the metropolis as a whole. The statistics given in this and the earlier paper refer simply to occasions upon which fog of some kind was recorded at some portion of the 24 hours, no regard being had either to the density or the duration of the element.

The results for each month, for each season, and for each year of the 33 years, are given in detail in the Table on p. 17. The averages at the foot of the Table show that for the period in question the mean annual number of fog days in London was 55, of which 45 occurred in the winter half of the year, October to March, and only 10 in the summer half, April to September. The results yielded by the monthly averages are slightly different from those given in the former paper, in which the observations employed extended over a period of only 20 years. For those two decades December was the foggiest month in the year, October coming next, and then, in order of frequency, January and November—proverbially regarded as the worst in the year. In the results now given for the longer period, December retains its unenviable position, but November comes second, then January, and, last of the murky quartet, October. The excess of fog in December as compared with November is greater than that existing between any of the other autumn or winter months.

The clearest month in the year is undoubtedly July, next to that

[1] "On the Prevalence of Fog in London during the 20 years 1871 to 1890," *Quarterly Journal Roy. Met. Soc.* vol. 18, p. 41.

June, and next again May, the average prevalence in the last-mentioned month being considerably less than in August. During the whole 33 years there were only 14 days on which fog was reported in July, and in the last 16 years of the period there were none at all. Six summers out of the 33 passed without any entry of fog, but only one spring and one autumn. The clearest winter in the whole series (that of 1876-77, which was also very stormy) had 9 days with fog; while the worst (that of 1890-91, a cold, quiet, anticyclonic winter) had as many as 50.

The totals for each of the past 33 years are depicted in Fig 1, the curve showing that the annual number of fogs ranged from 86 in 1886, 83 in 1887, and 75 in 1873 and 1889, to only 26 in 1903, and to only

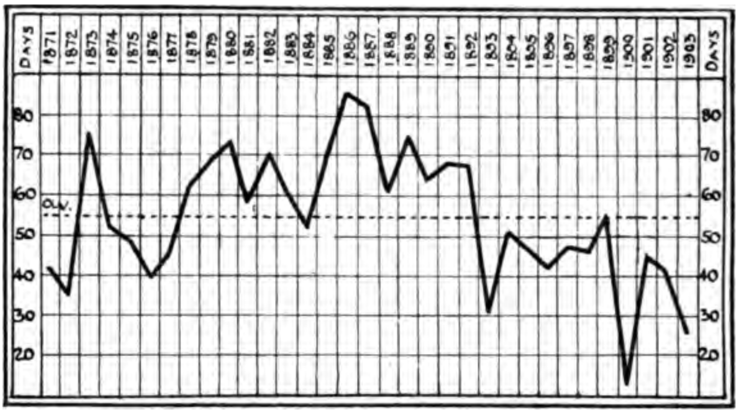


FIG. 1.—Number of Days on which Fog was reported in each year, 1871-1903.

13 in 1900. The absence of fog in 1900 was very remarkable, the total number of days being, as we see, only half that recorded in the next best year of the series. In addition to 1900 and 1903 there were only two other years in which the number was less than 40. Forming as it does the subject of the present paper, the most important feature shown in the diagram is, however, the gradual, though not steady, decrease in fog prevalence which is seen to have taken place in recent years. Dividing the 33 years into periods of 11 each, we have, for the first period, a mean annual number of fogs amounting to 55, and for the second period a mean of 69. In the third period the number has dropped to 41. In the first period the total annual number was above the average in 5 years, but below it in 6; in the second period it was above the average in every year but one; in the third period it was below the average in every year but one.

These crescendo and diminuendo movements are shown very clearly in Fig. 2. In preparing this diagram the 33 years have been divided into 11 periods, the mean annual number of fogs being given for each triennial period. It will be seen that in the first two periods the mean number was slightly below the average. After this there was a decided increase, materially checked, it is true, in the three-year period 1883 to 1885, but reaching a very pronounced maximum in the following three years 1886 to 1888. Since then a steady and uninterrupted decrease

TABLE SHOWING THE NUMBER OF DAYS ON WHICH FOG WAS REPORTED IN LONDON [BRIXTON] IN EACH MONTH, IN EACH SEASON, AND IN EACH YEAR OF THE 33 YEARS 1871 TO 1903.

Years.	The Months.												The Seasons.				The Half Year.		The Entire Year.
	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Spring.	Summer.	Autumn.	Winter.	Summer Half (April to Sept.)	Winter Half (Oct. to Mar.)	
1871	2	4	2	...	...	1	...	3	2	13	10	5	2	4	25	11	6	28	42
1872	3	2	6	...	1	...	1	2	...	6	4	10	7	3	10	10	4	39	35
1873	4	10	11	1	1	3	...	...	9	14	9	13	13	3	32	24	14	45	75
1874	7	11	5	1	...	...	...	2	5	3	11	8	6	2	19	31	8	59	53
1875	...	9	7	5	1	1	2	3	4	5	5	7	13	6	14	17	16	38	49
1876	12	3	...	3	...	1	...	...	6	5	9	1	3	1	20	22	10	32	40
1877	7	1	4	1	2	...	1	...	5	11	7	7	7	1	23	9	9	27	46
1878	7	8	...	3	1	1	...	1	7	11	10	14	4	2	28	22	13	40	63
1879	7	2	8	2	2	1	1	1	9	10	8	18	12	3	27	23	16	52	69
1880	19	6	7	3	1	...	1	2	8	11	7	9	11	3	26	43	15	68	74
1881	16	7	5	2	...	1	...	1	9	6	5	7	7	2	20	32	13	55	59
1882	12	12	5	3	1	...	1	...	7	9	5	14	9	1	21	31	12	47	69
1883	10	8	4	4	1	...	...	1	8	9	9	7	9	1	26	32	14	50	61
1884	6	5	7	2	...	1	1	2	6	4	15	4	9	4	25	18	12	43	53
1885	10	4	9	4	1	1	3	1	7	8	10	11	14	5	25	18	17	46	69
1886	8	14	9	3	4	3	1	4	5	13	10	12	16	8	28	33	20	60	86
1887	17	10	13	3	1	1	2	2	5	9	12	8	17	5	26	39	14	75	83
1888	9	3	1	2	...	2	...	...	9	15	7	14	3	2	31	20	13	42	62
1889	17	1	4	1	5	1	...	3	2	11	15	15	10	4	28	32	12	58	75
1890	5	12	4	1	...	...	...	...	5	10	8	20	5	0	23	32	6	62	65
1891	14	16	1	2	2	...	...	2	6	5	9	12	5	2	20	50	12	69	69
1892	9	6	6	4	...	...	...	1	...	12	15	15	10	1	27	27	5	47	68
1893	5	4	6	3	...	...	...	...	1	...	4	8	9	...	5	24	4	57	31
1894	6	7	7	...	...	...	...	4	5	6	6	10	7	4	17	21	9	32	51
1895	6	5	2	4	1	...	...	...	9	6	7	8	7	...	22	21	14	35	48
1896	9	7	2	2	...	...	...	...	...	5	10	8	4	...	15	24	2	39	43
1897	4	5	2	1	...	2	...	...	4	10	9	11	3	2	23	17	7	34	48
1898	13	1	5	3	1	1	...	...	4	5	10	4	9	1	19	25	9	49	47
1899	4	10	8	...	...	...	...	2	...	12	6	14	8	2	18	18	2	41	56
1900	4	3	2	1	...	...	...	...	...	...	...	3	3	...	...	21	1	41	13
1901	10	2	...	...	...	...	...	...	3	8	14	8	...	...	25	15	3	15	45
1902	2	12	6	2	...	...	...	1	3	4	8	4	8	1	15	22	6	50	42
1903	6	1	1	...	2	...	...	...	3	1	7	5	3	...	11	11	5	24	26
Averages	8·2	6·4	4·8	2·0	0·8	0·6	0·4	1·2	4·7	7·8	8·5	9·5	7·7	2·2	21·0	24·1	9·8	45·4	55·0

is shown, the mean annual number of fogs for each of the last four triennial periods being below the average for the entire 33 years.

That the recent decrease has not been confined to any one portion of the year will, I think, be seen even from a cursory glance at the figures in the Table. In the spring season the mean annual number of fogs rose from 8 in the first eleven years of the period to 10 in the second eleven years, but sank to 6 in the third. In the summer the mean for the first two series was 3, but for the third only 1. In the autumn the numbers were respectively 22, 25, and 15; while in the winter they were 22, 30, and 20.

The curve given in Fig. 2 suggests two questions of considerable interest. A period of 33 years is, it will readily be admitted, too short to yield evidence of any secular variation in the prevalence of fog (if

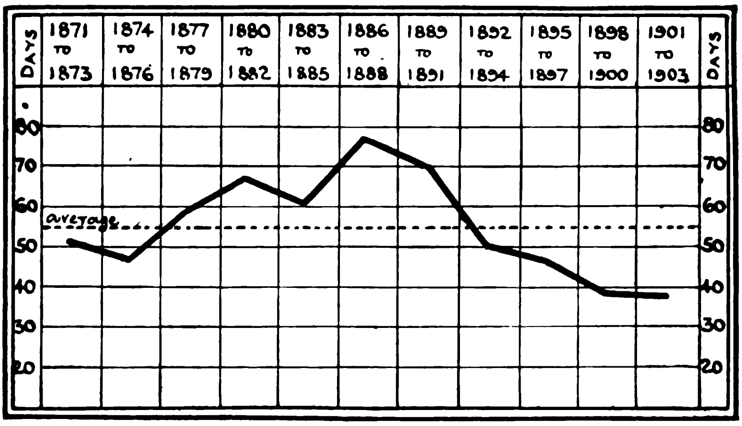


FIG. 2.—Mean Annual Number of Fog Days in each of the 11 Triennial Periods.

indeed such a thing exists); and it may therefore be asked, Did the comparative rarity of the phenomenon in the two first triennial periods constitute simply a minimum, which was not only followed, but also preceded, by a maximum? Supposing this to have been the case, is there not a likelihood of the recurrence of another maximum in the years which lie before us? To each of these questions it is, we fear, difficult to give any really satisfactory answer,—firstly, owing to the lack of reliable observations for the years prior to 1871; and, secondly, because the art of prophecy is, as every weather forecaster knows, a dangerous gift. There are, however, some considerations which seem to suggest that a negative reply might in each case be very fairly hazarded.

Before entering upon these speculations it is perhaps necessary to say that an intimate acquaintance with current weather changes leads very strongly to the opinion that an explanation of the increase, and of the subsequent decrease, of fog in London is not to be found in the prevalence of any corresponding changes in the meteorological conditions. The winter of 1890-91, the foggiest of the whole series, was, it is true, a season in which the anticyclone held almost undivided sway, and in which one would therefore, very naturally, have looked for an abundance

of such weather. Since then there has been no winter in which the atmospherical conditions have been quite so favourable to the production of the element, but in some an anticyclonic type has been sufficiently in evidence to lead one from former experience to anticipate a good deal of fog and mist. In several instances the expected has of course happened, but in not a few cases high-pressure systems of considerable intensity have arrived and departed without any fog worth speaking about, while in many other cases the visitation has assumed a comparatively mild form. It will, I think, be conceded even by any ordinary unscientific observer that, with very few exceptions, the fogs of recent years have been neither so dense nor so protracted as those with which Londoners were so painfully familiar 15 or 20 years ago.

The causes which have led to a mitigation of the pest must therefore be sought in other directions; and in order that some more adequate explanation may be advanced, it is necessary to consider for a moment what it is that conduces in so large a measure to the production of town fogs. The interesting experiments conducted some years ago by Mr. John Aitken pointed very clearly to the conclusion that in order that water vapour may become visible it is essential that the minute globules should have some solid particles to which they can attach themselves, and that these particles, or nuclei, are furnished by the dust which prevails in the atmosphere. In all populous centres immense quantities of this dust are generated by the imperfect combustion of coal, and the consequent formation of smoke.

The questions we have now to consider are, whether in the course of the 33 years under review there have been any causes which may have conspired to increase the production of smoke in the earlier half of the period, and to diminish it in the latter half. The observations from which our figures are derived were taken, it must be remembered, mainly at Brixton, a suburb which has witnessed considerable changes in the course of a generation. Within a radius of half a mile or so of the observing station hundreds of new houses have grown up, while still farther afield an extension of the same process has led to a complete union between the metropolis itself and neighbouring centres, which 30 years ago existed only as small country towns, separated from London by large open spaces. A similar change has taken place in other suburban districts, and the great increase of smoke, which has resulted from the erection of so many thousands of additional chimneys, may well have conduced to the growth of fog in the earlier half of the 30-year period.

But it may be fairly urged, the extension of London has been quite as marked in the latter half of the period as it was in the earlier; and how, in that case, are we to account for the marked diminution of fog which has taken place? The suggested reply to such an inquiry is that in the course of the last few years the smoke fiend has been attacked in so many ways that his power has very sensibly diminished.

Among the numerous agencies which have conduced to this very desirable result we may mention, first, the energetic efforts put forth by the Coal Smoke Abatement Society, which have been directed mainly to an enforcement of the law by which factories and large works are required to consume their own smoke. As a result of action taken

during the six years of the Society's existence, we learn that in the case of 68 large works, whose chimneys habitually polluted the atmosphere of London with dense volumes of smoke, the practices have been reformed to such an extent that for some months past they have not been observed to emit any smoke at all.

Another factor in the reduction of the evil has been the fitting in most of the larger, and in many of the smaller, modern dwelling-houses of improved forms of grates and stoves, permitting of a more perfect combustion of fuel than in the case of the old-fashioned kinds.

Another cause which has, in all probability, conduced to the reduction of London smoke has been the growing adoption in recent years of improved forms of lighting. The old-fashioned gas-burner, with its well-known capacity for the production of noxious carbonaceous fumes, is fast disappearing, and in its place we have the incandescent gas light, which emits far less smoke, and the incandescent electric light, which emits practically none at all.

Yet another agency in the purification of the London air has been the largely increasing use of gas stoves, both for heating and cooking purposes. These stoves, which were at one time seen only in large establishments, are now fitted in many even of the smallest dwelling-houses, and every encouragement to their use is afforded (very naturally) by the gas companies, the application of the penny-in-the-slot principle enabling all but the very poorest to avail themselves of their undoubted benefit. When we consider how many thousands of open smoke-producing grates of the worst possible form of construction have been replaced, to a partial extent at least, by the cleaner and more convenient gas stove, it can, I think, hardly be denied that this has certainly not been one of the least potent agencies in the reduction of the great evil in question.

The geographical situation of London on the banks of a large river is of course eminently favourable to the development of fog and mist, so that from a purely meteorological point of view the position of the metropolis is, we fear, incorrigible. With a cleaner air, however, there is little doubt that fogs would diminish in frequency, and even when they did arise, the vapour particles would not be impregnated, as they now are, by the pestilential products arising from an imperfect and wasteful consumption of fuel.

DISCUSSION (December 21).

THE PRESIDENT (Capt. D. WILSON-BARKER) said that Mr. Brodie's paper dealt with a subject of general and very practical interest, though its title might be somewhat misleading, because, as he points out, we are hardly likely to get rid of the fog demon. He (the President) was inclined to believe that fogs are entirely dependent on the meteorological influences acting on certain local conditions: a proof of this is that while a thick fog may prevail in some places, other areas, even in the immediate neighbourhood, may be perfectly clear. He did not think that fogs (that is, a real fog, and not a smoke cloud) would diminish with the abatement of the smoke nuisance, but they would be cleaner: sea fogs were often quite as thick as any experienced in London, but they were neither black nor dirty. There was a tendency, he thought, to exaggerate the importance of the influence of dust on fog. The whole subject deserved serious discussion,

and he was sure the Fellows would join him in thanking Mr. Brodie for bringing it forward.

Mr. W. MARRIOTT said that as the discussion had been postponed from the previous meeting it had afforded him an opportunity of tabulating his own observations of fog during the 27 years 1878-1904 at West Norwood. But before giving the results he wished to make a few remarks on Mr. Brodie's paper. The observations given by Mr. Brodie in the table were for the Meteorological Office station at Brixton, with a few fogs at other places thrown in. He (Mr. Marriott) thought that it was not quite the thing to claim that these represented London as a whole, as the title of the paper led one to suppose. Mr. Brodie in the first paragraph stated that the statistics referred to all the occasions upon which "fog of some kind" was reported, but in the latter part of the paper he spoke about "town fog." This led one to suppose that he had dealt almost entirely with what was popularly called "London fog," and not fogs in the ordinary or meteorological acceptance of the term. Mr. Brodie ought to give a clear definition of what he meant by the term "fog." The International Meteorological Congress of Vienna had recommended certain symbols for use in describing various meteorological phenomena. They had adopted the same symbol both for fog and mist, which they evidently believed to be one and the same phenomenon. The symbols were used in this country by the observers of the Royal Meteorological Society and of the Meteorological Office. Some years ago a monthly table of phenomena as observed at the Second Order stations was regularly printed in the *Meteorological Record.* Mr. Marriott showed lantern slides of several of these tables, and pointed out how Mr. Mawley's records at Addiscombe, Croydon, confirmed his own observations at Norwood, the two stations being only about 3 miles apart.

The following table gives the number of days in each month, from 1878 to 1904, on which he had observed fog of any kind—either dense or slight—at West Norwood. In the latter part of 1889 he moved to another house, barely half-a-mile from the previous site. He used to think that this change of position had been the reason why he had not recorded as many fogs during the latter years, but the variations in the curves followed so closely those given by Mr. Brodie that the diminution in the number of fogs seemed to be an undoubted fact. The number of days on which he had observed fog was greatly in excess of that recorded at Brixton, which was only 3 miles from West Norwood.

Mr. Marriott said that he had often found that the value of the observations at many stations depended largely upon the occupation, as well as the keenness, of the observer in noting the various meteorological phenomena. In the returns which come to the Society, some had a considerable amount of information about the various kinds of weather noted during the day, while many others had no remarks at all. It would be unfair to suppose that no phenomena or weather of any kind were experienced at these stations, simply because the observer did not report them. If an observer had a sedentary occupation or was not able to be out during the day, he would miss many phenomena which ought to be reported. He (Mr. Marriott) had endeavoured to keep as careful a watch on weather changes and phenomena as possible, and the observations had almost all been taken by himself, except during the months of July and August, when he was sometimes away from home. Mr. Brodie gave for the year 1900 the total of only 13 days of fog. This he (Mr. Marriott) believed to be a mistake, as it was not confirmed by his own observations at West Norwood. In the *Daily Weather Report* for that year forecasts of fog were given for 24 days, excluding Sundays. This also tended to show that the 13 days were too low,—otherwise the forecasts were erroneous.

On page 18 Mr. Brodie said "that an intimate acquaintance with current weather changes leads very strongly to the opinion that an explanation of the

increase and of the subsequent decrease of fog in London is not to be found in the prevalence of any corresponding changes in the meteorological conditions." He (Mr. Marriott) regretted that Mr. Brodie had not given the results of his investigation in this matter, as even negative results are often very valuable. He believed, however, that there was a considerable connection between fogs and calms or very light airs. He showed lantern slides on which were given curves of the number of occasions on which the velocity of the wind at the Royal Observatory, Greenwich, was less than 200 miles per day. These curves followed those of the days of fog at West Norwood in a most remarkable manner. It therefore appeared that absence of wind was very favourable to the formation of fog.

DAYS OF FOG AT WEST NORWOOD, 1878-1904.

YEAR.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1878	11	14	0	3	1	3	1	0	3	12	13	16	77
1879	8	7	11	13	8	4	2	3	15	17	22	24	134
1880	21	8	14	6	8	10	6	13	16	12	15	7	136
1881	26	19	13	7	7	7	5	5	18	16	8	14	145
1882	17	17	12	7	8	5	4	6	18	15	7	20	136
1883	15	14	16	12	10	7	2	12	16	14	11	17	146
1884	14	9	16	15	9	16	7	19	16	16	19	11	167
1885	19	14	19	13	8	7	14	16	16	13	22	22	183
1886	13	24	14	10	9	5	1	11	12	16	19	15	149
1887	24	16	15	9	12	7	4	2	8	18	17	19	151
1888	12	13	14	8	5	6	9	6	20	18	10	19	140
1889	21	4	10	15	15	9	0	1	11	14	18	20	138
1890	7	22	6	13	11	8	6	12	15	14	14	27	155
1891	15	23	6	10	9	7	3	2	11	10	15	10	121
1892	16	12	14	14	3	3	2	3	8	15	17	13	120
1893	15	5	13	10	3	0	1	1	1	5	5	10	69
1894	7	6	14	6	1	1	0	7	16	15	7	12	92
1895	14	15	9	6	8	3	1	2	16	12	10	10	106
1896	13	13	4	6	1	0	0	0	1	9	13	8	68
1897	9	7	4	2	0	4	1	3	10	14	16	12	82
1898	10	5	10	4	5	2	2	0	6	9	16	6	75
1899	5	15	12	3	3	3	1	0	0	15	13	18	88
1900	8	12	16	9	0	1	1	3	5	7	7	6	75
1901	17	15	9	2	6	0	0	1	6	13	16	12	97
1902	4	16	10	9	7	1	1	4	11	15	12	6	96
1903	8	6	1	1	8	7	4	0	7	2	10	17	71
1904	13	4	10	3	5	3	1	0	7	16	24	18	104
Mean	13·4	12·4	10·8	8·0	6·3	4·8	2·9	4·9	10·7	13·1	13·9	14·4	115·6

Mr. J. E. CLARK first referred to the relation of smoke and fog. During the past 7 or 8 years he had been in the habit of jotting down the number of quarters of an hour that it was necessary to resort to artificial light at his office, at 112 Wool Exchange to September 1903, and since then in Finsbury Square, E.C. Both offices were exceptionally well situated for light, and his desk was about 12 ft. from large windows. His original object in making these notes was to check the cost of extra electric light required by day darkness, but the observations proved so interesting that he had sent the values for the winter half-year, October to March, for 4 years to the *Meteorological Magazine* for January 1902. From his figures it was found that the darkness increased after 9 o'clock, and reached its maximum at 10.15, the actual number of dark quarters of an hour for the 4 years being 36 at 9 o'clock and 53 at 10.15. Taking the years 1897-1903, the total number recorded rose from 54 at 9 o'clock to 74 at 10.15,

followed by a fall to 30 at 11.45 ; and a slight rise afterwards takes place to 33 at 12.15, whilst the minimum was 27 at 12.45. These figures included cases of darkness when there was no actual fog. The lightest time of the day in the winter months being just before 1 o'clock is followed by a rapid increase of darkness (27 to 37) at 1 itself. Then it fell to about 30 till 2 o'clock. After this it rose rapidly, and by 4 o'clock reached 90. He thought, therefore, that his notes indicated some connection with smoke. The rise in the figures after 9 o'clock was probably due to the lighting of office fires, while the rise at 12 and again at 1 o'clock depended on increased activity by the restaurants. Turning next to the values year by year, he pointed out that beginning with 178 quarter hours in 1897-98 and 141 in the next winter, the number then increased regularly to 622 in 1901-2, but were only 542 in 1902-3, and 264 last season. This year (1904), so far, was much worse, having already given 456 to the present time (December 21). Comparing, next, dark days, these had increased regularly from 17 in each of the first two years to 68 in 1902-3, dropping to 43 last year. The earlier years ought perhaps to be a little higher, as he (Mr. Clark) had been hardly strict enough in including *all* days when the light was required more than a few minutes before sunset. But this would not account for the contrast to the sudden drop in Mr. Brodie's curve in 1901-2. The day darkness curve, indeed, was deflected slightly upwards for that year.

Turning next to the excessive fog noted by Mr. Brodie from 1884 to 1891, Mr. Clark said that he had compared this with one based on his observations of the visibility of the West Riding Hills from York. The nearer range of foothills was 25 miles distant; the main range visible, including Great Whernside, 40 miles off. The intervening districts had no smoke-producing centres whatever. Yet it was very striking that, from 1883 to 1891, visibility was below the average, and most especially so before 1890, when Mr. Brodie's fog-curve was at its maximum. Indeed, his fog-curve, inverted, was very similar to the visibility curve during the 15 years of observation 1883-97. It would be remembered by astronomers that the same period, up to 1891, was a very bad time for making observations. Now this lack of visibility was very reasonably assigned to the effect of the dust distributed by the Krakatoa eruption. Had not this same dust much to do with the excessive fogs during the same period?

Mr. A. A. Pearson, in a letter to Dr. W. N. Shaw, said :—" I am sorry to miss the discussion on the decrease of London fogs, since, assuming that the decrease in the last 20 years has not been due to temporary and exceptional causes, I should have ascribed it to rather different causes from those suggested by Mr. Brodie. As regards the greater use of gas, electricity, etc., I should have thought that the large increase of houses with ordinary fireplaces would have counterbalanced any benefit from this cause. But the large and increasing area covered by paved streets or slated roofs, where every drop of water that falls is at once carried off, and of which the temperature must be slightly raised by the warmth of the houses, the lighting, and the human and animal traffic, would naturally diminish the supply of damp for the formation of fogs. At present the river and the parks are the great breeding-grounds of damp for fog formation, and their relative proportion to the total area diminishes yearly. I have often thought that if we could absolutely eliminate all smoke and dust production in general in London we should revel in skies of an almost Italian blue, owing to the constant drainage away of all surface water. At Wimbledon, where I live, we very frequently now have a dense fog in the valley of the railway on days when London is comparatively clear."

Dr. W. N. Shaw remarked that various suggestions had been put forward as to the cause of the diminution of the number of observations of fog at Brixton. He attached most importance to Mr. Marriott's comparison of the winds at Greenwich with the frequency of fog at Norwood. Certainly the wide difference

in the frequency of fog in the winters of 1901-2 and 1902-3 discovered by the fog inquiry, of which a report has been recently published by the Meteorological Council, was largely to be accounted for by the difference in wind velocities of the two winters. But meteorological phenomena were generally due to a combination of many causes, and to establish the natural relation of cause and effect required the demonstration of many intermediate steps and was necessarily a long and intricate process.

Mr. C. Harding was of opinion that the wind was a very important factor in connection with the matter under discussion. On looking through the Greenwich volume for 1900, the year of minimum fogs, he had found that there were only 5 days on which the horizontal movement of the wind was less than 100 miles. Again, in 1884, a fairly foggy year, there were 9 such days, and even these 9 seemed less than the average number. The daily average movement of the wind at Greenwich was about 300 miles. It had been a common remark that recent winters were much more windy than usual, and the absence of calms was noticeable. He did not think Mr. Brodie was at the bottom of the fog question. Why not argue that the rainfall was decreasing? During the last 10 or 12 years, nearly every year was dry, taken as a whole, with the notable exception of 1903.

The Hon. F. A. R. Russell, in a letter to the Secretary, said:—"I am sorry to be unable to be present to-morrow at the discussion on London fogs. I think it certain that the number of dense dark fogs at the level of the streets is less than 30 years ago, owing first to the very large extension of dry surfaces of houses and pavement and surfaces above the temperature of the ground, even above the temperature of the air near the ground in the country; and secondly to the very widely extended mass of air actually warmed above the outside temperature by fires and their products, as well as by contact and radiation from comparatively warm walls and roofs. The higher temperature of the whole area of central London gives rise to an ascending column of air which lifts the smoke from the lower strata. But there is still the possible condition of a very low temperature with active radiation through a dry upper air, producing in a certain state of the air a dense ground fog; and when this condition occurs the fog may be as dense, dark, and oppressive as in former times, and probably at least as highly charged with carbon dioxide gas. Recent years have been unusually free from these fogs with great cold, but London has not itself to thank for the immunity."

Dr. H. R. Mill said that, interesting as Mr. Brodie's paper was, he feared that it lost some value by being based on records at more than one place. It would have been more representative of changes in London fog, in his opinion, if it had dealt with the Brixton record only, and not included some occasions when Brixton was free of fog. It would, of course, have been very much better if the records of several stations had been taken, the mean of which might fairly have represented London. As regards the year 1900, the south of London appeared to have enjoyed a remarkable immunity, and he had been led to compare the figures with those for Camden Square, with the curiously discordant result shown below—a result the more surprising because of the close agreement for the year 1899, also quoted, and the fact that, as a rule, the figures for Camden Square have shown a much smaller fog-frequency than those for the south of London.

Comparison of Fog-Frequency.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Brixton, etc., 1899	4	10	8	...	...	...	...	2	...	12	6	14	56
Camden Sq. ,,	2	9	10	...	2	...	1	1	4	12	9	9	59
Difference . .	+2	+1	−2	0	−2	...	−1	+1	−4	0	−3	+5	−3
Brixton, etc., 1900	4	3	2	1	...	...	...	...	...	...	...	3	13
Camden Sq. ,,	11	6	3	3	...	...	...	2	1	7	8	8	49
Difference . .	−7	−3	−1	−2	0	0	0	−2	−1	−7	−8	−5	−36

He had not been able to go thoroughly into the Camden Square record, but he had compared Mr. Brodie's figures, assuming them to represent the variations in fog-frequency for London with the frequency of rainy days and the amount of rain at Camden Square, which are certainly representative of London as a whole. The result when plotted as curves was extremely interesting. For the 10 years from 1871 to 1880 the curves of rainfall and rain-frequency were similar and opposite to that of fog-frequency; in other words, a year which had frequent fogs had few rainy days or little rain, and a year with few fogs had many rainy days or much rain. From 1881 to 1884 the fog-frequency, rain-frequency, and total rain varied together, but from 1885 onward the inverse relationship frequently reappeared, though not with such regularity as in the first 10 years. This relationship is not surprising, for if years in which fogs are frequent are those in which anti-cyclonic conditions have been predominant or at least unusually common, they should be dry years as well, while years of frequent cyclonic disturbances ought to be wet and free from fogs. He would welcome a classification of the last 30 or 40 years according to the types of atmospheric pressure which prevailed in each. Such a classification would be most helpful in discussing the variations of all meteorological phenomena, and he hoped that it might be found possible for some one in the Meteorological Office, or perhaps for the Meteorological Council in its official capacity, to supply this desideratum.

Commander W. F. CABORNE, C.B., was desirous of thanking Mr. Brodie for his valuable and interesting paper upon a subject which was being forcibly brought home to Londoners by the atmospheric conditions experienced by them that day. He agreed with the President that it was impossible to prevent or abolish fog. It was true that Sir Oliver Lodge had been successful in dissipating fog over a small area by means of electricity, but it was evident that, owing to the great cost of generating electricity, at any rate at the present time, this agent could not be extensively employed in coping with the evil in our vast metropolis. But while it was impossible to abolish fog, there was no reason why in towns and great cities it should not be rendered very much cleaner than was usually the case. As a member of the Executive Committee of the Coal Smoke Abatement Society, he claimed that that association had already done, and was doing, much to attain this very desirable end, and that it could, and would, do an infinitely greater work, were it not hampered in its labours by want of funds, which prevented the employment of more than one inspector to detect and note infractions of the law, when at least half-a-dozen should be available. Nevertheless, during 1903—the figures, of course, were not yet completed for 1904—some 2000 observations were taken, and 1278 complaints were forwarded to the proper quarters. Then it was to be borne in mind that the Smoke Prevention Clauses of the Public Health Act only applied to such places and things as factories, clubs, restaurants, locomotives, and steamers, and did not embrace private dwelling-houses, which latter, it was almost needless to say, played a by no means unimportant part in the creation of smoke nuisance. Considerable difficulty, too, had been encountered in getting certain of the various local authorities to put the Act in force, and this, in a few instances, would seem to have been due to the fact that some of the members of those bodies were themselves offenders, and feared lest they should be put to expense. However, it had been proved to demonstration that the use of satisfactory furnaces and appliances brought about a distinct diminution in the consumption of fuel, and thus effected an important financial saving. One of the most smoky districts, if not the most smoky district, in London was West Ham; and as there was a light drain of air from the eastward, it was very possible that western London was in a measure suffering that day for the sins of West Ham. While the London County Council, the Westminster City Council, the Port Sanitary

Authority, and most of the Metropolitan Borough Councils were now working in unison with the Coal Smoke Abatement Society, the Local Government Board had practically declined to exercise its paramount powers over some recalcitrant public bodies. In its path of duty, the Society would energetically continue its course, until such time as the Metropolitan Area was in a satisfactory condition with regard to the abolition of smoke nuisance; and then London fogs would be robbed of more than half their terrors.

Mr. F. J. Brodie, in reply, said that, in the course of a long connection with the Society, he had noticed that the discussion following the reading of a paper was occasionally more important and more interesting than the paper itself. This appeared to be so in the present instance, and the Society might be congratulated upon the fact, that the insignificant memoir he (Mr. Brodie) had had the honour of submitting to their notice had elicited so many valuable remarks from those eminently qualified to speak upon the subject. With regard to the observations made by the President as to the unimportance of the dust theory, seeing that dense fogs were often experienced at sea, it was worth remembering that dust particles were found in all parts of the globe, though not of course to anything like the same extent over the ocean as over the land, and more especially in the neighbourhood of populous centres. With regard to the strictures which had been passed as to the use of the Brixton observations, he (Mr. Brodie) justified their employment on the ground that they were published in the official reports of the Meteorological Office and were accessible to all. West Norwood and Croydon were quite outside the metropolitan area, and with regard to the figures quoted by Mr. Marriott it was not clear whether they referred to observations of fog only, or of fog and mist. If they included both elements, it was easy to understand why the numbers were higher than those given for Brixton. The impossibility of a London fog prevailing with a decided breeze was of course well known to all, and it was therefore not surprising to find that with much wind at Greenwich there was little fog. There was, however, so far as he (Mr. Brodie) was aware, no reason to suppose that there had been, within recent years, a gradual increase in the strength of the wind such as would account for the steady decrease in fog-prevalence. The suggestion made by Mr. Pearson, that the decrease might be due to the increasing area covered by paved streets and slate roofs, might account for the lessened frequency of fog, but would scarcely explain the change in its character; the thick, smoky kind (present in a very disagreeable way at the very time the discussion was in progress) being far more rare than it was 15 or 20 years ago. The decided tendency to fog exhibited during the last three months of 1904 had led many persons with short memories to imagine that something quite phenomenal was occurring. A few statistics might tend to dispel such notions. The average number of fogs in December was 10, but up to the date of the meeting (the 22nd) only 5 had been experienced, although two-thirds of the month had elapsed. During the previous three months—September to November—there had been 22 days with fog, but that number was only 1 in excess of the average. Throughout the year there had been, so far, 16 fogs short of the average number for the whole twelve months, so that, if the remaining 10 days proved foggy, the total annual number would still be 6 less than the normal. With regard to the remarkable absence of fogs in 1900 it was doubtless surprising to learn that, while Brixton had reported the element on 13 days only, Camden Square had had as many as 39 days. He (Mr. Brodie) had looked into this matter, and had found that at Greenwich there were 30 cases; but 3 of the fogs occurred at night, and might easily have escaped the notice of ordinary observers, while 13 others were classed as "slight fogs." He had also examined the reports published quarterly by the Royal Botanic Society, Regent's Park, which gave a total for 1900 of 15 fogs.

It seemed very probable that these wide discrepancies between the reports of various London observers were due to varied ideas existing as to the precise meaning to be attached to the words "fog" and "mist" and the occasions on which each term should be employed. The suggestion made by Dr. Mill that the weather for a long period—say the last 30 years—should be classified under the headings "cyclonic," and "anti-cyclonic," and that the conditions prevailing with each type should be examined in detail, was undoubtedly a most valuable one, but the amount of time and labour involved in such a discussion would, it was clear, be very large. In his (Mr. Brodie's) opinion there was no reason to suppose that the meteorological conditions in recent years had been so peculiar as to account for the great diminution in fog-frequency. The reading of a former paper on the subject, in which attention was drawn to the increasing prevalence of the element, was followed, as had now been shown, by a complete turn in the opposite direction. It was to be hoped that no such change would occur to falsify the predictions modestly put forth in the present paper. If such, indeed, proved the case, he would claim shelter from obloquy by pointing to the improvement enjoyed in the last few years, and would submit that his sins of omission and commission might fairly be allowed to counterbalance each other.

Capt. A. Carpenter, R.N. (in a communication to the Secretary), said:—"Anything that Mr. Brodie puts his hand to is sure to be authentic and to the point. The eleven-year periods into which he divides his data for 33 years somewhat alarmed me, as I feared that the sun-spot cycle was perhaps going to be accused of giving us these terrible yellow perils. I am quite in agreement with the author that anything like an improved combustion of coal in this great city will tend to diminish the opacity; and the support of the public should be accorded both to the Coal Smoke Abatement Society and to the efforts of the London County Council. In comparing frequency of fog, however, it is very necessary to consider whether the winter was a wet and windy one, or whether relatively dry and quiet; or, as Mr. Brodie puts it, whether cyclonic or anti-cyclonic weather was most prevalent. A good example, that such is the case, is given by the year 1900, which has been shown to have been a year of remarkably little fog. Looking up the *Meteorological Record* for that year, I find that January had exceptionally heavy rainfall, was mild, and gales occurred 2nd to 4th, 6th, 9th, 15th, 17th, 18th, and 22nd to 30th—in fact, there was no opportunity for fog to collect. February—first half of the month cold, last half mild. Rainfall exceptionally heavy. Gales or strong winds on 2nd, 10th, 11th, 13th to 20th, and on 27th. Thus from 3rd to 9th was the only chance for fog, and on two of these days there was heavy rainfall. March was dry and fairly cold, but from 13th to 24th there were continuous strong winds. The same may be said for the last three months of the year, in which (1) the rainfall was above the average over the country, (2) November and December were mild, and (3) in December there were 20 days of strong winds.

"I do not hold out any hope of a fog clearing by electricity, or any other cure. Prevention can be exercised, and should be exercised, and there is little doubt that the old wasteful fireplaces are gradually being replaced by more economical forms."

Fog in London, December 6, 1804.

The following extract from the *Times* of Saturday, December 8, 1804, shows that London a hundred years ago suffered from fog even as it does at the present day:—

"The extremely thick fog on Thursday occasioned many mistakes. Numbers of political *Quidnuncs* delivered the most absurd prognostications on public

affairs, from being totally unable to *see their way*. *Lovers* broke their *assignations* by mistaking the houses of their fair idols. Misers felt a stagnation of profit, because they could not *see* to take their *money* without the expence of artificial light. The *tallow chandlers* have, however, profited exceedingly; and many an *idler* was absolutely compelled to the horrible *drudgery* of reading a book, in order to *consume* a little *heavy* time, and get through an *intolerable* day. The most *quick-sighted* were puzzled; and even on the river no small confusion occurred among the *craft*."

"BAD PUN.—A would-be wit, speaking of the unusual *fog* on Thursday last, observed, that 'the *fog* was so *thick*, that it could not be *mist*'!"

Discussion of Meteorological Observations in relation to Solar Phenomena.

At the Meeting of the International Meteorological Committee held at Southport in 1903, a sub-committee was appointed to organise a Commission to deal with the correlation of solar and terrestrial changes. This Commission met at Cambridge during the session of the British Association, August 18-23, 1904. Sir Norman Lockyer was elected President, and Sir John Eliot, Secretary. Among the decisions of the Commission bearing on Meteorological subjects were the following:—

"That, in the first instance, for the purpose of comparison with solar phenomena, the meteorological observations to be considered should be monthly means of pressure, rainfall, and temperature (including maximum temperature and minimum temperature)."

"That the members of the Commission be requested to communicate to the Secretary a short report on the data available in their respective countries, and the number of years over which they extend."

"That the members of the Commission be requested to make suggestions with regard to additional stations from which it is desirable that data should be obtained in view of the comparison of solar and terrestrial data."

The questions of the selection of meteorological stations and of the establishment of additional meteorological stations were again considered, and it was resolved that the members of the Commission should hand in their list of selected stations to the Secretary after the close of the British Association Meeting, and that it would be desirable that observations should be obtained from two stations in the Pacific. The stations selected were Tahiti and Numea, to be established by the French Meteorological Bureau.

In connection with the observations of solar radiation, it was resolved, that observations of the transparency of the air should be made, more especially (*a*) on the visibility of distant and high mountains when possible; (*b*) photometrical observations of Polaris.

A circular was to be addressed to the various meteorological organisations, asking them to send to the Secretary for the purposes of the Commission a copy of the publications of their offices embodying the data specified in the resolution of August 19, and that the organisations be also requested to obtain and forward copies of similar publications from the Colonies and Dependencies of their respective countries.

It was also decided that a circular should be sent in the following terms:— The Commission desire to call attention to the concluding paragraphs of Professor Violle's report to the International Meteorological Committee, 1903, and would be greatly obliged if the Commission could be informed of the arrangements for observing solar radiation, adopted at the observatories of the various meteorological organisations, and the methods employed to render the observations comparable with those of other observatories.

HURRICANE IN FIJI, JANUARY 21-22, 1904.

By R. L. HOLMES, F.R.Met.Soc.

(*Abridged.*)

[Read November 16, 1904.]

I HAVE the honour to lay before the Society some particulars of a hurricane that caused great destruction of property in Fiji on January 21-22, 1904. Its behaviour throughout was peculiar, differing from any previous storm that we have hitherto experienced.

I wrote to the Sydney Observatory, to Mr. H. A. Hunt, F.R.Met.Soc., the Acting Meteorologist, and also to Mr. H. A. Lenehan, the Acting Government Astronomer, who both very kindly offered to investigate the whole affair. I forwarded to Mr. Hunt copies of all statistics that I could collect, and continued to send more as they reached me from the observers. The mails, particularly between here and Levuka, are very slow and irregular, and it is only quite lately that I received their final decision. Mr. Hunt's letters are given in an appendix, but I may say at once that we disagree altogether, particularly as to the direction the storm came from. Mr. Hunt believes it originated in the east, either within the confines of the group, or near it in an embryonic condition. He complains, and rightly so, that the tables of statistics are in general most unsatisfactory. The aneroids were very seldom, if ever, compared with a mercurial barometer; indeed, there is only one such in Levuka. In this group forewarnings, to any extent, are of course impossible.

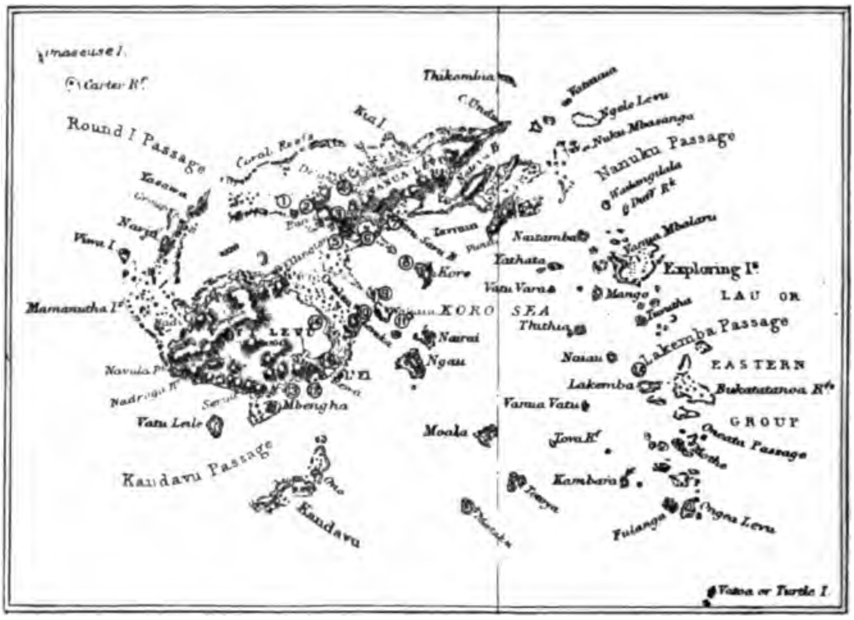
There is in Buchan's *Handy Book of Meteorology*, 2nd edition, p. 275, a caution expressed to navigators and others as to navigation in these seas. It was originally taken from a paper by Dr. C. Meldrum, of Mauritius:—

"As the trade wind in front of a revolving storm often blows in strong gales with a falling barometer over many degrees of longitude, and the direction of the wind, especially at a distance, is far from being at right angles to the bearing of the centre, severe losses have occurred in consequence of vessels, having the wind at S.E., running to W. or N.W., with a view of crossing the storm's path, under the impression that the centre bore N.E. In place of bearing N.E., when the wind is from S.E., the centre may bear N. or N.W., and if the storm be travelling towards the S.W., as is often the case, a vessel steering to the W. or N.W. may be running to her destruction," etc.

The North-west monsoon had been more prevalent last season than I ever knew it before. In fact, so constant were Northerly winds all through the wet season—December to March, both inclusive—that I lately sent to the Sydney Observatory a copy of all daily observations on wind and rain for five months ending April 30, 1904, thinking that perhaps such information might assist to unravel the great problem of droughts in Australia. Buchan says: "It is to be specially noted that it is when the monsoon is pressing southward on the S.E. trade that storms occur." In this instance the monsoon met no resistance from the trades till it entered the Fiji group. The sun was far to the south of the equator, travelling north though near its summer solstice, and nearly vertical at noon. New moon occurred on the morning of January 18.

Mr. Holmes found that there was considerable difference of opinion as to the origin and course of the storm, which in his opinion came from the north-west. A further difficulty was experienced with regard to the lack of uniformity in the observations, and also to the uncertainty attaching to the barometer readings, as the index errors of the instruments were not known.

Particulars were received from 15 places in the Fiji Islands, the positions of which are shown on the accompanying map.



Map of the Fiji Islands.

Yadua, a small island (**No. 1**), lies 12 miles west of the extreme westerly point of Vanua Levu, the second largest island in the group. No white resident lives on the island, but the Rev. C. O. Lelean got from his Catechist there an account that can be relied on, viz. that on Wednesday, January 20, the wind changed from West to about West-north-west, and blew tremendously hard from that point for several days. Old houses and weak trees were blown down, but no serious damage done.

Korovatu (**No. 2**), Mr. Hughes' plantation opposite Yadua on the mainland. The same report exactly.

Nagere (**No. 3**), at the eastern end of Bua Bay. The Rev. C. O. Lelean took careful observations throughout. From a very long list of hourly observations I select the following, viz. :—

	in.	
20th—noon	29·59	Wind S.S.W., strong.
,, midnight . . .	29·39	,, S.W. ,, and rain.
21st—6 a.m. . . .	29·07	,, N.W., furious gale.
,, 11 a.m. . . .	28·90	,, ,, ,, (first min.)
,, 1 p.m. . . .	28·94	,, ,, ,,
,, 6 p.m. . . .	28·80	*Min.* ,, th. rain, great storm.
22nd—6 a.m. . . .	29·07	Westerly wind, moderate.
,, 9 p.m. . . .	29·40	,, ,,

Not much damage done about Bua Bay.

Delanasau (**No.** 4) (my home and plantation), lies 14 miles north-east from Bua Bay, and about 23 miles north by east from Bouwalu. I took hourly or half-hourly observations from 3 p.m. on the 20th till 2 a.m. on the 22nd. The lowest mercurial barometer reading, all corrections applied, was 29·056 ins. at same hour as in Bua, viz. 6 p.m. on 21st. The following are a few of the readings (all corrected); the house lies back from the sea, the north coast of Bua province, one mile, and is elevated 70 feet above sea-level: viz. :—

	in.	Temperature.	
20th—3 p.m. . . .	29·588	83°	Wind W.S.W.
,, 10 p.m. . .	29·526	82	,, ,,
21st—1 a.m. . . .	29·366	80	,, W.
,, 3 a.m. . . .	29·286	80	,, W.N.W.
,, 6 a.m. . . .	29·212	80	,, N.W. by W.
,, 9 a.m. . . .	29·156	80	Wind throughout this period varied between W.N.W. and N.W. by W., never passing either of these points.
,, 11 a.m. . .	29·130	79	
,, noon . . .	29·130	79	
,, 1 p.m. . . .	29·146	79	
,, 4 p.m. . . .	29·088	80	
,, 6 p.m. . . .	29·056	80	
,, 9 p.m. . . .	29·136	80	
,, 12 p.m. . .	29·156	79	
22nd—6 a.m. . .	29·196	78	
,, 9 a.m. . .	29·260	79	
,, noon . . .	29·316	80	
,, 6 p.m. . .	29·426	81	

Note here, as farther south, a slight rise after first minimum at noon on the 21st. The wind for five days after the 22nd blew always from North-west to North. The true direction of the wind was always carefully noted, and allowed for variation of the compass, which here is 9°·40′ East.

The rainfall in thirty-six hours ending 8 a.m. on 22nd was 6·94 ins. Thunder in the early part of the blow, none after. It blew tremendously hard on night of the 20th, and all day on the 21st till midnight, doing much damage, not so much to houses as to trees and crops. Cocoanut-trees suffered severely; some blown down. Fronds on north-west side were broken and battered, and an immense number of immature nuts were knocked off or destroyed, falling for months after when the broken butts of the fronds gave way. Here, as with the natives, many bread-fruit trees were blown down, and the large crop of fruit then coming ripe—every one destroyed; bananas of course fell wholesale; and, I regret to say, a young plantation of para and ceara rubber trees suffered severely. The salt spray driven by the wind from the ocean, one to two miles away, blackened the leaves of many plants, chiefly thousands of aloes lining fences.

The storm divided on the high hills on the north-western portion of the island. Most of it passed down towards Bouwalu, as we shall see presently; the part that passed here continued its south-east course.

West and south-west from here, overland, not much damage was done till we reach the native village of Dama, on the coast, half-way between Bua Bay and Bouwalu, where many native houses were blown down, also a large new wooden Wesleyan chapel.

Bouwalu, or **Cocoanut Point** (**No.** 5), the chief native village of the province, and residence of the head chief—the Roko Tui Bua—and site of a large new Government hospital, etc. The terrific force of wind and sea here was one of the reasons why the Levukaites asserted that such could only be caused by a true hurricane; hence the statement that was put by Captain Wilson and others that the hurricane, having travelled up from the south, here turned and went back on its track southward. But neither here nor

farther along the coast to south-east was there any change of wind; it blew always from about North-west to West-north-west. The worst of the wind and rain was on the evening of the 21st. One aneroid reading was given at 28·80 ins. at 6 p.m., but this was copied from Rev. C. O. Lelean's notes in Bua. The minimum at Bouwalu was probably much lower. On all Thursday (the 21st) the sea overflowed the whole site of the village, kept so by low atmospheric pressure, and the wind blowing on-shore. All houses were wrecked and the lower ones washed away. A very fine Wesleyan Methodist church, 60 ft. by 30 ft., of wood, was utterly destroyed by wind and flood. All the hospital buildings, including the doctor's fine residence, except a portion of the patients' wards, were blown down, and great hardship suffered, by the sick especially, and by the doctor himself. On Thursday night the wind and sea abated a little, but it blew and rained hard all Friday. The *Yarabale* cutter, owned by Mr. Coward of Tai Levu, was carried inland by the sea and dashed against a cliff, and then utterly destroyed by a landslip. A small island close to was completely broken up and disappeared.

My son Charles, Government Surveyor, passing here a week later, took several very interesting photos, showing the awful destruction everywhere, copies of which are sent to the Society. He thus describes the country about: "Right along the coast as far as Kubulau it is in a truly deplorable state, and looks as if a volcanic eruption had taken place. The reports were in no degree exaggerated—it would be hard to do so. Every nut tree up the valley is simply a bare pole. All the houses in the town were simply wiped out. Natives are putting up small houses out of remains of old ones. There is not a scrap of new thatch to be obtained. Gardens either washed out or as bare as a table. Landslips are very numerous. The lee sides of the hills have patches of green bush left, but the windward sides are—well, I never saw anything like it. The ground is all bare; there is not a vestige of green, just bare poles and gaunt arms. The little island between Bouwalu and Cawalevu has disappeared and left a sandbank. Piles of coral along the reef edges, some of the lumps being 15 ft. long and 6 or 8 ft. high."

Solevu, the Roman Catholic Mission station, 6 miles south-east of Bouwalu, suffered to nearly the same extent.

At **Nadi** (**No.** 6), farther along the coast, only 12 houses out of 150 in the district were left standing.

At **Wainunu** and **Kubulau** (**No.** 7), 17 miles east by north from Bouwalu, matters were, if possible, worse. The provincial chief, Roko Tui Bua, was there at the time on a visit, and gave me a clear account of it all. Asked what direction the wind blew from, he pointed again to North-west. Here, besides the destruction of native property, several lives were lost. The *Ratu Luki* cutter was driven out to sea with four men on board and never heard of after. The cutter *Adi-Kalou* was saved by the crew cutting away the mast, but of four men who tried to swim ashore, three were drowned.

Near Wainunu are some plantations of white settlers, at least one large cocoanut estate, and farther inland a large tea and cocoa estate. Removed back from the coast, they did not suffer much.

Near Kubulau to the east lies Savu Savu Bay. One plantation there, owned by Mr. Tomson, suffered very much from a furious gale from North-west, coming across the island, the extension of the storm that did us so much harm here at Delanasau. Thence to eastward there was little or no harm done.

We now leave Vanua Levu for the south, and henceforth have to do with a genuine revolving hurricane.

Koro (**No.** 8), an island of 48 square miles in extent in the middle of the Koro Sea. It lies about 46 miles south-east from Bouwalu, and 35 miles north-east from Levuka. It was stated that the wind blew first from South-east, then

from North-west, after the manner of a hurricane travelling southwards. I could not, however, get any particulars as to the time the storm began and ended, nor any aneroid readings—nothing, in fact, except that it raged for 17 hours. The notice in the *Polynesian Gazette* stated—" Hurricane wrecked every town in the island of Koro ; worst ever known. Any amount of wreckage ashore at different parts of the island. One life lost. Natives report the yards of a square-rigged ship at the town of Tavua. All native food destroyed and rooted up. Plantations destroyed, and cocoanut trees broken, and all chance of copra at an end for three to five years " !

Mokogai (No. 9), a small island 4 to 5 square miles in extent, lies about 12 miles east-north-east from Levuka, and about 22 miles south-west from Koro. Mr. J. Sinclair, living there, sent some interesting readings of his aneroid, with corrections to apply, which I have done, but with rather vague directions of the wind.

	in.	
20th—10 a.m.	29·83	Wind S.
,, 4 p.m.	29·73	,,
,, midnight	28·83	Great storm, S.
21st—3-6 a.m.	28·36	Hurricane, S.
,, 10 a.m.	28·53	,, E.S.E.
,, 6 p.m.	29·17	,, ,,
,, 7 p.m.	28·97	,, ,,
,, 9.20 p.m.	28·23	Calm.
,, 11 p.m.	28·35	N.W. hurricane.
,, midnight	28·60	N.N.W. ,,
22nd—1 a.m.	28·89	,, ,,
,, 6 a.m.	29·17	Moderate gale.
,, 9 p.m.	29·79	Fresh breeze, N.

To the 4 a.m. entry on the 21st is appended the word "calm," and about this in particular I wrote for information, but got none. Damage done was, outsiders say, very great. One report added, " 30 head of cattle were killed by falling trees." This I doubt very much.

Levuka (No. 10). The great destruction of house property in this the former capital of Fiji was fully described in the newspapers. Levuka lies on the east side of Ovalau, the area of which is about 43 square miles. It is very mountainous, and surrounded by coral reefs, inside which is the harbour. Nearly every house was more or less injured, many completely wrecked. Not many vessels in harbour at this time of year. The barque *Morelands*, half loaded with copra, dragged her anchors 4 miles to north and was then wrecked. The following are some of the principal readings of a mercurial barometer, the property of Capt. D. Robbie, Warden, taken and kindly sent me by Capt. F. L. Langdale ; but there is no note as to correction to apply for temperature or altitude ; very important considerations, as the temperature in these tropical storms continues very high, say 80° on an average.

	in.	
20th—noon	29·55	Wind S.W.
,, midnight	29·20	,, S.
21st—1 a.m.	29·10	,, S.E.
,, 3 a.m.	29·07	,, ,,
,, noon	29·35	,, E.
,, 9 p.m.	29·00	,, S.E.
,, midnight	28·50	,, S.
22nd—1 a.m.	28·35	Calm 20 minutes.
,, 3 a.m.	28·50	Wind S.W.
,, 6 a.m.	28·90	,, W.

The gale finished off in N.W.

On the 21st, 3 a.m., there was thus a first minimum with little change of wind, a rise till noon, and again a fall till 1 a.m. on the 22nd, when the true

minimum was registered; but the wind did not apparently change to North-west for some hours, if direction was carefully noted. Throughout the 20th there was a furious gale from about South-west, and on the night of the 21st still worse, till it reached its climax at about 1 a.m. on the 22nd. A difference of opinion was expressed as to whether a real calm was experienced as above noted.

Wakaia (**No. 11**), 12 miles east-north-east from Levuka, an island owned by Captain Langdale, who sent me some particulars of the hurricane, which passed directly over it, taken by Mr. P. Straube, the manager, but most of his papers were lost in the fallen houses, and much property destroyed, so unfortunately the data are very few and meagre:—

	in.	
20th—6 p.m.	24·40	Wind S.
,, midnight	29·10	,, S.E.
21st—4 a.m.	29·20	,, S.
,, 8 a.m.	29·40	,, N.E.

Gale from North-east and East all day. Towards dusk aneroid again fell. At midnight wind about South-east, hurricane force. Bar. **28·35 in.**, then calm with stars out and puffs from North from 12.15 to 2.15 a.m. on the 21st. Then gale from South-west, finishing off at North-west. The report adds: "The direction of the wind, owing to the constant roar and the necessity of keeping in sheltered places, may not be accurately given." All houses were blown down. The lighthouse on the north end of the island escaped with little damage.

Suva (**No. 12**), the capital, lies about 45 miles south-west of Levuka. Here there was a very heavy gale, the worst being on Thursday to Friday p.m. Not much damage done, just far enough away from the vortex to save disaster. But while the wind was so long in South and South-east great anxiety was felt. No communication was possible with Levuka, the telegraph wire being broken. Some trees, fences, and very weak houses only were destroyed. Captain P. M. Land of the s.s. *Clyde* gave me a long list of aneroid readings taken on board during three days and nights, of which I select the following:—

	in.	
20th—9 a.m.	29·70	Wind S.S.W.
,, 9 p.m.	29·60	,, S.
,, midnight	29·53	,, ,,
21st—3 a.m.	29·46	,, S.S.E.
,, 9 a.m.	29·39	,, S.E.
,, noon	29·33	,, ,,
,, 6 p.m.	29·27	,, ,,
,, 9 p.m.	29·24	,, ,,
22nd—3 a.m.	29·10	,, S.
,, 5 a.m.	**29·06**	,, ,,
,, 8 a.m.	29·09	,, S.S.W.
,, noon	29·15	,, S.W.
,, 9 p.m.	29·36	,, W.S.W.
23rd—6 a.m.	29·40	,, S.W. by S.

Those data can be thoroughly relied on, Captain Land being a very careful observer; always excepting probable index errors.

Navua (**No. 13**), about 21 miles south-west of Suva, the site of a large sugar mill, a considerable population, and very extensive cultivations of sugar and bananas especially. A correspondent in the *Fiji Times* writes: "We had a very bad blow here for two days. Every banana tree in the district has been blown down. A six-feet flood over high tide, and all low-lying lands under water. Sugar-cane does not seem at all damaged."

Rewa river and **Tai Levu** (**No. 14**), the extreme eastern portion of Viti Levu, the largest island in the group. From there I could get no reliable informa-

tion. There were great floods in the Rewa, and from there up north near the coast the gale was severely felt in most places. The westerly edge of the hurricane would pass along going south. Taking this as such, it may be said that the total width of the destructive portion of the hurricane may be set down at 70 to 80 miles.

Lakemba (No. 15). This island, which has an area of about 12 square miles, lies in the Windward, or Lau, group, and is distant from Levuka about 165 miles east by south; and from Suva 190 miles east-south-east. Letters from Rev. J. W. Butcher and Mr. G. Gerrish point out the important fact that so early as the 19th there was a great storm from South-west.

	in.
20th—9 a.m.	28·98
21st—noon	29·50
22nd—8 a.m.	29·24
,, 10 a.m.	29·20
,, noon	29·15
,, 1 p.m.	29·14
,, 2 p.m.	29·13
,, 4-5 p.m.	29·10
23rd—7 p.m.	29·55

The direction of the wind reads rather obscurely, as no dates or hours are given, only this general statement: "Direction of wind was first from South-west, it changed round to East-north-east and Northerly, from which point it blew strongest. It finished off at South-west, going backwards, with great force. It blew harder here than on the islands to east and west of us. At Tavuca, 30 miles to north, little or no damage was done, while to south and south-west all suffered more than those to north or north-west."

Summary—Particulars of double minima at the principal stations:—

		in.	Wind.
Delanasau, No. 4.	—First, 21st—11 a.m.	29·130	W.N.W.
,,	Second, 21st—6 p.m.	29·056	,,
Mokogai, No. 9.	—First, 21st—3 to 6 a.m.	28·36	Calm or E.S.E.
,,	Second, 21st—9.20 p.m.	28·23	*Calm*, E.S.E. before it, followed by N.W.
Levuka, No. 10.	—First, 21st—3 a.m.	29·07	S.E., and continued Easterly till midnight.
,,	Second, 22nd—1 a.m.	28·35	S. to S.W., finishing off at N.W.
Suva, No. 12.	—One min., 22nd—5 a.m.	29·06	South for hours before and after.
Lakemba, No. 15.	—First, 20th—9 a.m.	28·98	S.W., probably glass lower in night previous, *stormy*.
,,	Second, 22nd—4-5 p.m.	29·10	

The hurricane of January 21-22, 1904, resembles in some respects the one that passed down the Somosomo Straits, between Taviuni and Vanua Levu in March 3-4, 1886, a stronger blow than this last one. In both instances the centre of the storm followed the wide openings between high lands. A description of the earlier hurricane is given in my paper, *Quarterly Journal Roy. Met. Soc.*, vol. 13, p. 37.

APPENDIX.

Letters from Mr. H. A. Hunt, F.R.Met.Soc., Acting Meteorologist, Sydney Observatory.

April 26, 1904.

DEAR SIR—I wish to thank you cordially for your letter containing data relative to the Fiji hurricane of January 21-22, 1904. Unfortunately the information is not so full or widespread as we should wish, and it seems a great pity where so much interest is apparent that there should be such a want of uniformity amongst your observers. It would be a good thing, and perhaps ultimately help towards a solution of these storm problems, if you could induce those residents in the Fiji group who have meteorological instruments, and are in the habit of taking observations, to agree with you as to some common method of work. The instruments should be tested with some standard, and the amount of error determined. Also the readings should be all taken at some hour agreed upon, so that results may be intercomparable.

The different barometer readings given during the late hurricane were fairly constant, and, taken separately, very satisfactory ; but the task has been difficult, and, it might be said, doubtful, by the fact that the index error of each instrument was unknown—your barometer of course excepted. Again, the observations were in a majority of cases taken at different hours, consequently the results from each station had to be taken separately.

We have carefully plotted the data from the various sources on some sixty charts, showing the momentary variation in movement, and the changes that took place with regard to the hurricane vortex. We have no data antecedent to the storm, but are of opinion that it approached the Fiji Islands from the East in an embryonic state, its passage being interrupted by the land friction of the islands Vanua and Viti Levu. This dormant depression being checked in its westerly progression, and, lying over the Goro Sea, gradually gathered gyratory force, possibly from higher pressure at remote distances, while the outer isobars remained relatively constant in location, the inner and more sinuous ones of the vortex oscillated between Levuka and Cocoanut Point. This movement accounts for the apparent double centre. As far as data guide us, the vortex filled up without affecting any horizontal movement.

Enclosed you will please find the map cutting, for which, and also for all the data supplied by you, our cordial thanks are submitted.—I have, etc.,

H. A. HUNT, Acting Meteorologist.

Approved.
H. A. LENEHAN, Acting Government Astronomer.

June 7, 1904.

DEAR SIR—Many thanks for your supplementary data from Lakemba ; this is one of the points we were particularly anxious to get information from.

We also are endeavouring to procure data from Samoa and Tonga.

When we are in a position to discuss the atmospheric conditions over an extensive area, it is possible that we may have to modify the views advanced relative to the storm ; but up to the present additional evidence mainly confirms the opinion based on the earlier observations.

You will note we agree with you that it is possible the hurricane was checked in its progress by resistance of land.

When it is understood that the depth of the hurricane was possibly less than a mile, the effect on an attenuated atmospheric body in conflict with

immovable land area, though of comparatively small elevation, may be readily appreciated.

We are much indebted to you for your returns of rain and wind from Delanasau Bua.

Undoubtedly the weather is controlled largely by the varying solar energy in the tropics. Curiously, we are at present moving to procure momentary data from that region to north of us, and also from India; thinking that with the easterly atmospheric progression we are more concerned with tropical conditions to the west than to the east of us.

However, your data is exceptionally valuable, and will enable us to make the investigation more conclusively than otherwise would be possible.

Many thanks, also, for the detailed climatic statement at Delanasau Bua. Extending over such a long series of years makes it very valuable, and we will gladly give it a place in the next annual report, of course acknowledging you as the source.—I have, etc.,

H. A. HUNT, Acting Meteorologist.

Approved.

H. A. LENEHAN, Acting Government Astronomer.

DISCUSSION.

Capt. A. CARPENTER, R.N. (in a communication to the Secretary), said:—
"When reading Mr. Holmes's original paper before abridgment, I was struck by the keen interest shown by himself and other prominent residents in the Fiji group as to the probable path followed by this destructive storm, and I think we are much indebted to him for the great trouble that he took to collect data, however poor, from all parts of the group which would further the elucidation of its movements.

"Mr. Holmes was of opinion that a North-west gale preceded and accompanied the hurricane; but I think that he has not sufficiently taken into account the difference in amount of incurvature between winds blowing near the outside and those nearer the centre of such a storm; and that he had not realised that it is possible, owing to such variation, for a revolving storm to approach from a great distance without any practical change in the direction of wind until its centre is passing the observer at its minimum distance.

"In this case, when that point had been reached, the storm was checked by land, and, after a slight vacillation that accounts for two minima, it moved off to south or south-south-east, *directly* away from Mr. Holmes's own observation spot, thus still maintaining the wind in his locality in a fairly steady West-north-west direction. Mr. Holmes's own observations show wind at West-south-west on the 20th, and this was the natural indraught towards a depression forming to the east of the Fiji Islands. When Mr. Hunt wrote his letter of April 26, he was not in possession of the observations at Lakemba Island, and in his second letter he states that he may have to modify his views.

"I think that we may safely assume that the storm commenced to move off to the south-south-east about 9 p.m. on Thursday the 21st, being at that time over Makongai Island. At 1 a.m. on 22nd it was between Levuka and Wakaya Islands, and at 5 a.m. at its least distance from Suva (on the south side of Viti), the barometer being then at its lowest and the wind from South at that place.

"The next news is from Lakemba, on the south-east of the group, which tells us that the glass was falling all the 22nd, with wind ranging from East-north-east to North. At this latter point it blew hardest with the barometer lowest, at 4 to 5 p.m. The wind went on backing, until it finished off South-west, which shows that the storm passed not very far off to the southward. No

doubt after the first move onwards from Makongai to the southward it curved gradually to east-south-east, and this is borne out by the report from Lakemba that islands to south and south-west suffered more damage than those to the northward.

"As Mr. Hunt writes, further information is desirable from Samoa and from Tonga, and I hope it has been forthcoming, and that Mr. Hunt has been able to track the path of the storm still farther. I think that we may safely leave the matter in his hands. It is to be regretted that no report of the state of the sea on these coasts is furnished for the 19th and 20th. The east side of Koro Island should have given ample warning by this means, the heavy swell of the cyclone having probably shown itself there as early as the 19th. Of course the ideal warning for such a disastrous visitor would be given by wireless telegraphy from a lighthouse in Nanuku passage."

Commander M. W. C. Hepworth, C.B. (in a communication to the Secretary), said :—"There appears to be very little more to be said about this paper than what Mr. Hunt has already conveyed in his interesting letters to the author. I think, with Mr. Hunt, that the disturbance approached the Fiji group from the eastward ; but probably from some point north of east. It seems likely that the storm developed additional energy after entering the group ; that after passing south of the island of Koro its progress was arrested on its near approach to the high land on the large island of Viti Levu ; that the core deepened when in the neighbourhood of Levuka, and that the storm-field recurved soon afterwards.

"The monsoon season is the hurricane season in Fiji, and in the Coral Sea December and March, at the commencement and end of the season, being the months during which hurricanes most frequently occur : at intervals, it is said, of three or four years. But strong winds, occasionally attaining gale force, other than those associated with tropical revolving storms, are experienced in, and in the neighbourhood of, the Fiji group during the monsoon season. I have not experienced a hurricane in Fiji, but from the late Mr. J. D. Vaughan, who was Government Meteorologist at Suva and a Fellow of this Society, and also from Capt. Woolley, who was Harbour-master at that port, I understood that the force of the wind in the hurricanes which visit the group cannot be estimated by the amount of damage done to property, because the houses on the islands are lightly built and the cocoa-nut trees easily uprooted. Both of my informants appeared to be of opinion that the wind experienced during the passage of a revolving storm in those parts does not, as a rule, attain so high a velocity as it usually attains in visitations of a similar character in other tropical regions where they may be looked for.

"I desire to express my thanks to Mr. Holmes for a paper that has been full of interest to me."

Scottish National Antarctic Expedition.

We are informed by Mr. W. S. Bruce that the Argentine relief ship *Uruguay* sailed from Buenos Ayres for the South Orkney Islands to relieve the meteorological party at the station there about the middle of December. We may therefore expect the arrival of Mr. R. C. Mossman about the end of February.—*Scottish Geographical Magazine*, January 1905. (See also pages 14 and 74.)

THE STUDY OF THE MINOR FLUCTUATIONS OF ATMOSPHERIC PRESSURE.

By W. N. SHAW, Sc.D., F.R.S., and W. H. DINES, F.R.Met.Soc.

(Plate I.)

[Read December 21, 1904.]

Among the most noticeable features of the curves obtained from barographic records in this country, are occasional well marked but comparatively small fluctuations superposed upon the more general sweep of the surges of atmospheric pressure characteristic of these latitudes. The fluctuations are represented by irregularities in the curves, of various amplitudes and durations. Whatever be the ultimate cause of these fluctuations they represent, so far as the trace is concerned, actual changes of pressure. The most conspicuous examples are shown during the incidence and progress of thunderstorms, when the sudden fluctuations may be of the order of a tenth of an inch. The comparison of the traces from barographs in various localities leaves no doubt that the fluctuations during thunderstorms are due to travelling variations of pressure.[1]

A closer investigation may lead to the establishment of a definite connection between the minor fluctuations of pressure and other meteorological phenomena, and may thus throw light upon their origin. It is in the hope of promoting an effective investigation of this character that the present paper has been written.

The paper describes an apparatus designed to magnify the minor fluctuations, and at the same time to disentangle them from the general barometric surges. Mr. F. Napier Denison, in a paper read before the British Association at Dover (*B.A. Report*, 1899, p. 656), described an apparatus, which he called the Hydroaërograph, designed to show the barometric fluctuations on a magnified scale, to facilitate the study of the minor variations. The general surges are magnified in like proportion. Messrs. Richard Frères make an instrument, the statoscope, which also shows the variations of pressure on an enlarged scale. Its recording pen can be brought back to its zero line at any time by opening a tap. Since our apparatus was constructed we have learned that Prof. von Bezold has used the slow leak of air-pressure through a narrow opening to eliminate the large pressure surges in an instrument to be read by eye. The instrument here described, which was designed by Mr. Dines at Mr. Shaw's suggestion, combines the recording of variations upon a magnified scale (twenty-fold) with the practical obliteration of the general surges, through the operation of a small leak. It thus records, with adequate fidelity, comparatively rapid variations and no others.

The instrument (Fig. 1), like the Hydroaërograph of Mr. Denison and the statoscope of M. Richard, depends upon the expansion and compression of air. The use of the leak, to keep the pen within suitable limits on the paper, has the additional advantage of rendering the instrument independent of slow variations of temperature. Rapid variations of

[1] See *Report of the Meteorological Council* 1900-1901. Plate II., "Records of the Thunderstorms of July 27, 1900," p. 86.

temperature are avoided under the ordinary conditions of installation of the barograph, by surrounding the air chamber with non-conducting material. Under such conditions the variations of pressure due to changes of temperature are slow, and leak away without producing any appreciable disturbance of the trace.

It is proposed to call the apparatus the "Micro-Barograph."

FIG. 1.—Micro-Barograph.

DESCRIPTION OF THE MICRO-BAROGRAPH.

The essential parts of the instrument are, first, a closed vessel containing air, subject to pressure approximately equal to the atmospheric pressure, and, second, a mechanical arrangement by which the variations of the difference of the pressures inside and out are recorded. For the first part a metal cylinder of about one-third of a cubic foot capacity is provided. It must be placed in some position where the temperature is constant, or can only change slowly, and to attain this end it may be inclosed in a larger cylinder or wooden case, the intervening space being packed with feathers or some other non-conducting material. In order that the pressure inside may not differ much from that outside, a very small leak is allowed. This does not interfere with the changes of short period, because the time is too short to allow the pressure inside and out to equalise, but when a steady rise or fall of the barometer occurs, the leak comes into play and prevents the pen from wandering far from its mean position. The leak might be replaced by a mercury trap, that opened automatically when the difference reached a certain value, or was opened at fixed intervals by the clock.

The variations of pressure are transmitted to the pen by the means shown in diagrammatic form in Fig. 2. A hollow cylindrical bell, A, floats mouth downwards in a vessel containing mercury. The interior communicates with the air reservoir through the pipe B. It is clear that an increase of internal pressure, or what must amount to the same thing, a decrease of atmospheric pressure, will raise this cylinder in the mercury. The cylinder is pivoted at C to the end of the short lever DC, the whole system, including the pen P, the pen arm EE, and the counterpoise weight H, is free to turn, about a horizontal axis, in a vertical plane about the point D. The length PD being twenty or more times that of DC, the motion of the cylinder is greatly magnified. It is essential that the friction of the pen on the paper shall be inappreciable, and to secure this the pressure of the pen must be very slight. The pen arm is therefore made of light steel ribbon, bent as shown in the diagram, or is a

light aluminium frame. In either case its weight is carried on the point of a steel needle G, which rises through holes drilled in the ribbon or frame, and it can turn freely round this needle. It is balanced so that without the pen it is in equilibrium. The pen is a steel crow-quill nib, and when it is put in position it overloads one side, but there would be no tendency to swing round the needle towards the clock drum if G were vertical. To supply the necessary tendency, which is requisite to bring the pen against the paper, the steel needle G is slightly inclined to the vertical, but remains perpendicular to CD; and in this way the pen,

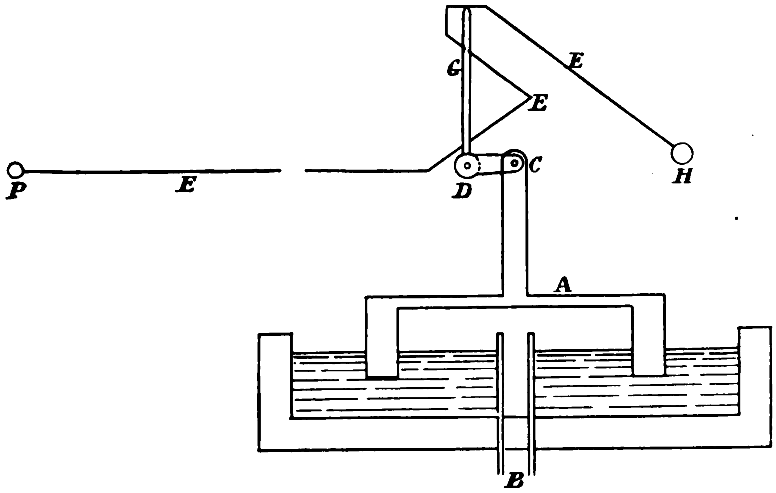


FIG. 2.

like a gate on a sloping gate-post, swings against the recording sheet of paper, which is carried by a clock-work drum in the usual manner. The pressure is uniform over a considerable range, and only amounts to a small fraction of the weight of the nib.

EXAMINATION OF THE INSTRUMENT.

The first instrument was constructed by Mr. Dines in the autumn of 1903. The movable bell in its mercury vessel with its pen carrier was placed upon the flat cover of a pressure-tube Anemograph, and the record was traced upon the drum of the Anemograph, so that wind and pressure fluctuations were both shown on the same sheet. The air reservoir was beneath the floor for better protection against changes of temperature. The bell was made of boxwood soaked in paraffin, and the leak was the casual leak through the wood. Subsequently, when Mr. Dines' instrument was found to give very satisfactory traces, three instruments in more compact form were ordered from Mr. F. L. Halliwell of Southport. The bell was made of aluminium, and the leak was provided for by a thermometer tube of fine bore communicating with the pipe which connects the air reservoir with the interior of the bell. In two of the instruments the packing of the air reservoir is by feathers contained in an outer metal case. In the third the packing used is wet sawdust, in order

to give greater thermal capacity. The lid of the case forms a table to hold the clock-drum and the rest of the apparatus.

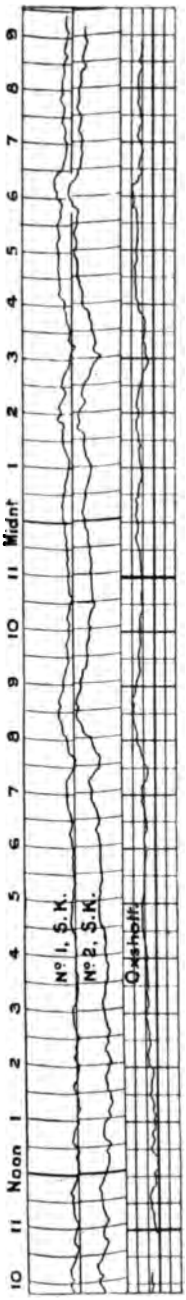
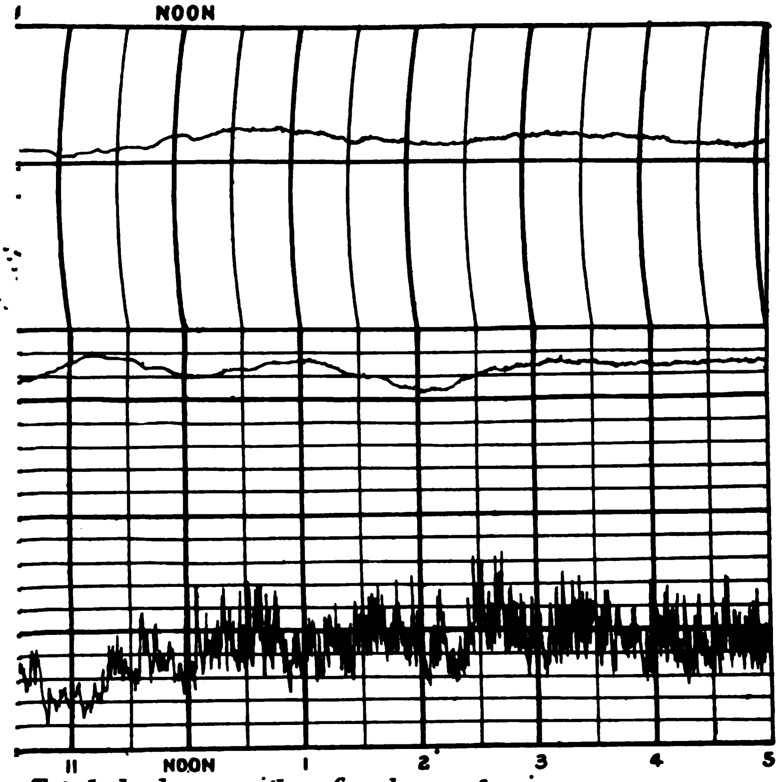


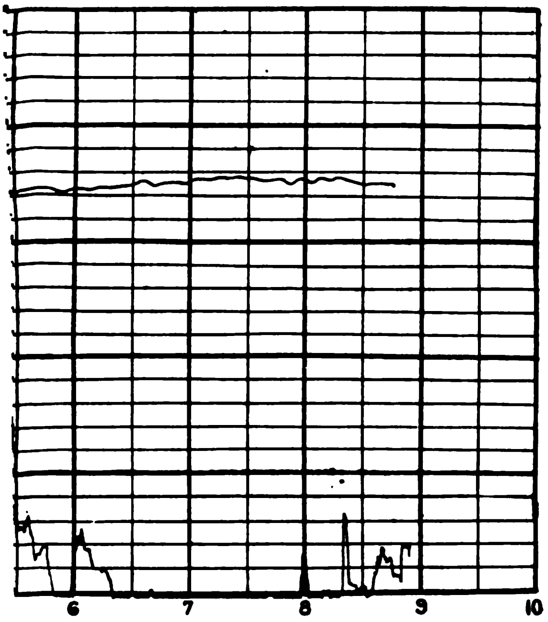
Fig. 3.—Comparison of Oxshott and South Kensington, March 25-26, 1904. (One-half of natural size.)

The first completed instrument of the new pattern was sent to London in April 1904, and was exhibited at the Conversazione of the Royal Society, on May 13. The second went to Fort Augustus to be used in connection with Sir J. Murray's limnographical investigation of Loch Ness. It was working there satisfactorily in July last. The third, the one packed with wet sawdust, arrived in London in May. A general view of the instrument is shown in Fig. 1.

The first point to be decided was whether two instruments would give essentially similar records. The possible results of differences of leak and of differences in the effect of temperature changes made it necessary to compare the records given by two instruments exposed to identical variations of pressure. For this purpose the two instruments sent to London, of which No. 1 was packed with feathers and No. 2 with wet sawdust, were mounted at 10 Moreton Gardens, South Kensington, side by side in a room on the first floor. Fig. 3, giving the traces for May 25-26, is a good example of the results of the comparison. The curves for the several instruments are indicated by the numbers marked against them. It is clear that the variations in the rates of the two clocks are responsible for greater differences in the traces than any other cause. As a matter of fact, during the trial of the instruments, some trouble was caused by the clocks stopping occasionally, and both have required the attention of a watch-maker. The traces for the following days May 26-27 (Fig. 4, Plate I.) show much less irregularity of the time scale. For comparison with the traces of the two instruments at South Kensington, those from Oxshott referred to the same time-scale are included in the diagrams. Oxshott is 13 miles to the south-west of South Kensington. The similarities and dissimilarities of the traces will be easily noticed, and it is unnecessary to describe them. There is clear evidence that the same disturbances affected both stations, but not simultaneously. Also the shapes of the traces caused by the disturbances show very varying degrees of similarity. In this connection attention may be specially called to the series of fluctuations between 8 a.m. and 11 a.m. on May 27. The records of the first of them are remarkably similar on all three instruments, with a time difference of half an hour between the two stations, but the similarity between the Oxshott and South Kensington records then disappears, though the two South Kensington records remain practically identical. At 9.45 on



Total darkness with a few drops of rain



May 27, No. 2 was dismounted for exhibition at the Royal Institution, and no trace was obtained from it beyond that time.

Sufficient comparison of the two instruments side by side had thus been made, and upon its return No. 2 was mounted in the wine-cellar as being most completely protected there against variations of temperature. The other was left on the first floor. The effect of the leak in each case was examined by blowing air through the leak tube into the apparatus, and allowing the pressure to equalise itself. The traces so obtained showed that No. 1 had a larger leak than No. 2. The trace of No. 1 only is reproduced (Fig. 5). Fig. 6 shows the result of the comparison

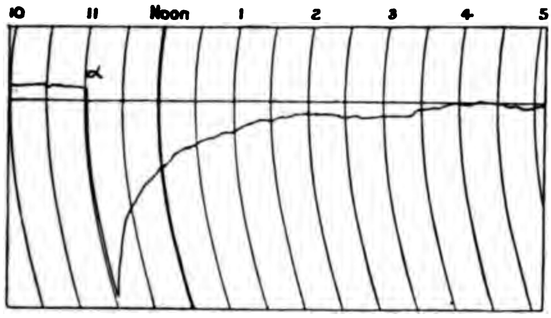


FIG. 5.—Effect of Leak No. 1, South Kensington. *a*, Air blown in through air tube. (Two-thirds of natural size.)

of the two instruments in their new positions. The run of the curves for twelve hours only (10 a.m. to 10 p.m.) is reproduced, as conspicuous fluctuations ceased in the afternoon. The continuation of the trace from No. 1 is shown in Fig. 8. The thickening of the line, most noticeable in the trace of No. 1, is due to rapid oscillations caused by wind. Upon close examination it will be noticed that during the remarkably sudden rise and fall shown on the trace of No. 1, which was associated with a short but almost explosive fall of rain and hail just before noon, the pen of No. 2 failed to write, and a little gap is left in its trace where the spire-shaped variation is shown by No. 1. All the other sudden changes are recorded on both, and on the whole the traces are extraordinarily similar. They afford satisfactory evidence that either instrument records the fluctuations of pressure in a manner sufficiently comparable for the purposes of the contemplated investigation.

The scale of the instruments, making no allowance for the effect of the leak, was designed (see Appendix, p. 50) to correspond with a twenty-fold magnification of the variations of a mercury standard. Indications of the small changes recorded have been found to correspond approximately with that scale, but no rigorous experimental determination of the scale has been undertaken.

The next example (Fig. 7, Plate I.) is also an exceptional one. It shows a series of very regular oscillations recorded at Oxshott on February 22-23. In this case the variations have a definite period which, however, becomes shorter as the oscillations diminish in amplitude. They commence at 11 a.m. with some considerable but irregular disturbances; at 4 p.m.

they become regular with a period of about 20 minutes. About midnight, there are four distinct maxima in the hour, between 2 and 3 a.m. there are 5 maxima, and about 8 a.m. there is a short series of waves with a period of 10 minutes.

The corresponding record of wind is reproduced in this diagram because it shows that the barometric oscillations are independent of the surface wind. It is true that there is an obvious variation of wind-force upon which the transient gusts are superposed, and that there is a suggestion of periodicity about the more general variation, but the barometric variations persist after midnight when the wind has died away, and are still shown during the calm between 1 a.m. and 3 a.m.

Other Examples of the Traces Obtained.

Records were obtained with the instrument in ordinary working, either at Oxshott or at South Kensington, from the beginning of 1904, till the middle of July, and for a considerable portion of the time at both stations. Traces were taken for about six weeks at Crinan during the kite experiments aboard H.M.S. *Seahorse*. All show considerable variety in the barometric fluctuations recorded. A few instances only will be noted.

As a rule the disturbances were confined to the daytime, the nights being comparatively quiet. Fig. 8 shows the night curve of July 2-3, following on the disturbed day curve represented in Fig. 6. It is important to notice this curve, because the sudden variations of the day had been associated with passing showers. In the early morning of the following day, however, represented at 6 a.m. in the trace, there was heavy rain, and a note at 8.15 marks, "very heavy rain commenced," but there is hardly any indication of sudden change on the trace. Thus the continuous heavy rain is not associated with sudden variations of pressure like those which indicate the passing shower. Fig. 9 shows by way of contrast a disturbed record for the night of June 15-16 at South Kensington, but such a trace is exceptional.

With regard to the last the immediate effect of gusts of wind is quite apparent in a rapid oscillation which produces a thickening of the trace, and a glance at the traces for a few days is quite sufficient to prove that the instrument gives a good indication of windy and calm weather. No one could for example fail to detect the general effect of the diurnal variation of wind-force in the traces from instrument No. 1. The instrument mounted in the wine cellar is less effective in this respect, but still it bears an appreciable record of the wind and its force. The fluctuations of pressure of longer period cannot, however, be attributed to the direct effect of wind on the building in which the instrument is housed. As evidence in support of this statement reference may be made to Figs. 4, 7, and 13, on each of which the Oxshott record of wind is reproduced. Attention has already been called to the record for February 22 (Fig. 7), and an examination of that for May 26-28 (Fig. 4), or for November 22 (Fig. 13), will confirm the conclusion that the small barometric fluctuations show no proportional relation to oscillations in the force of the surface wind.

The remaining examples show the traces corresponding to summer

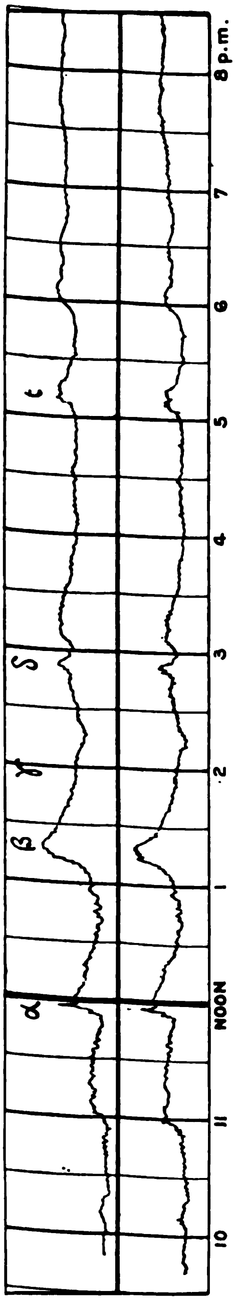


FIG. 6.—Comparison of Two Instruments at South Kensington in different Rooms during Showery Weather, July 2, 1904.

α, Explosive rain with hail. β, Cloud and heavy shower. γ, Brilliant Sunshine. δ, Dark cloud and rain-shower. τ, Squall, sudden cloud, slight shower.

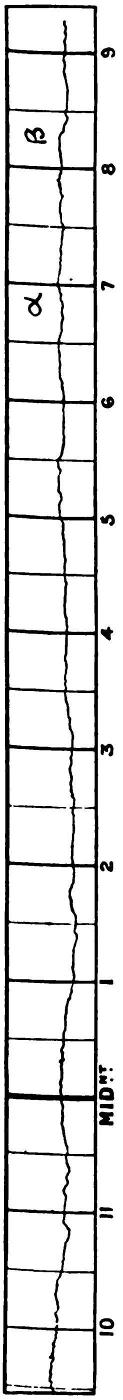


FIG. 8.—Quiet Night, South Kensington, July 3, 1904. α, Rain. β, Very heavy rain.

showers, except the last, which refers to the snow-showers of November 22. Two are shown on June 25 (Fig. 10) at 12.40 p.m. and 2 p.m., three on June 26 (Fig. 11) at 12.45 p.m., 3 p.m., and 5 p.m., two on July 1 (Fig. 12), at 4.15 p.m. and 5.50 p.m. Others of a similar character may be

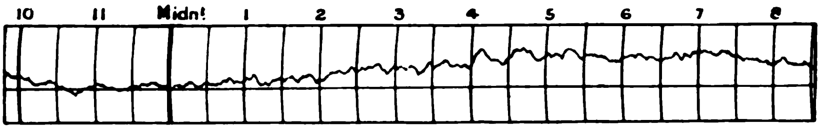


Fig. 9.—Disturbed Night South Kensington, June 16, 1904.

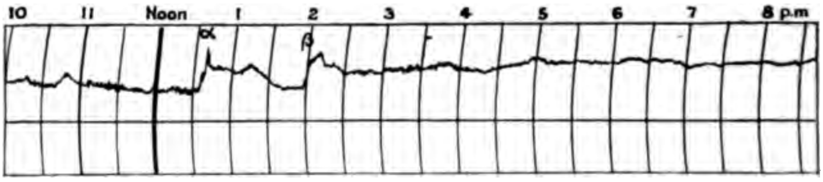


Fig. 10.—Windy Day with Squalls and Showers at South Kensington, June 25, 1904.
α, Squall, strong rain-shower. β, Dark cloud, slight rain.

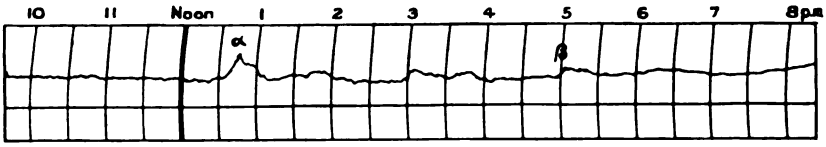


Fig. 11.—Showery Day at South Kensington, June 26, 1904.
α, Dark cloud, slight shower at 12.45, heavy shower at 12.50.
β, Heavy cloud passing from west, rain at 5.10.

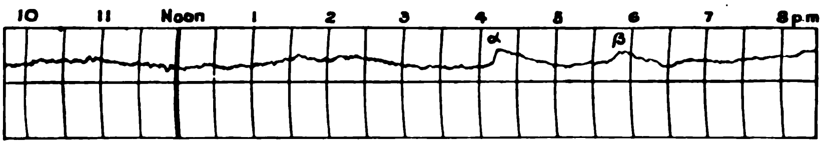


Fig. 12.—Fine Day with Moderate Wind, Showery Afternoon, South Kensington, July 1, 1904.
α, Cloud and rain after fine day. β, Rain.

seen in Fig. 3, between 8 a.m. and 10.30 a.m., and in Fig. 5 at noon, 1.15 p.m., 2.50, and 5.15 p.m. The trace obtained at Oxshott on November 22 (Fig. 13) is of a remarkable character. The sky was cloudy with snow at intervals, and there was a strong North-west wind. The snow-showers are marked by sudden and conspicuous increases of pressure.

Summer Showers.

The purpose of the instrument is to obtain information as to the nature of the disturbances and the causes to which they may be assigned. Among those which suggest themselves as likely to produce temporary fluctuations of the barometric curves are: (1) atmospheric billows passing along surfaces where there is discontinuity of density, in

a manner somewhat similar to ocean waves; (2) the passage of minute whirls, or cyclonic depressions of small scale; (3) variations of pressure due to the attraction or repulsion produced by electric stress as masses of air at different potential pass over; (4) the mechanical effects of wind; (5) the mechanical effects of rapid condensation of aqueous vapour.

The proper investigation of the relation of the variations of different shapes to each other, and to the meteorological conditions of the time of occurrence, require the co-operation of a number of observers, suitably placed, and attention will be directed here only to one class of phenomena which is represented frequently on the traces reproduced, namely, the passing shower of summer. Notes on the diagrams show the occurrence of thirteen examples of such summer showers. They are all in the day-time, and all have common characteristics, viz. a comparatively sudden rise of the barometer by a hundredth of an inch, more or less, followed by a gradual descent. The distribution noted on the charts is as follows:—

May 27. Oxshott, 8.15, T.S. ·28 in. rain. 9.45 T.S. ·38 in. rain. South Kensington, 8.45, dark cloud and shower. 9.10, very dark cloud and shower. 10.15 complete darkness, slight shower.

July 1. South Kensington, 4.15, cloud and rain after fine day. 5.50 rain.

July 2. South Kensington, 11.53 a.m., explosive rain and little hail. 1.15 p.m., heavy rain shower (brilliant sun at 2 p.m.). 2.50, rain shower. 5.10, squall, sudden cloud, slight shower.

June 25. South Kensington, 12.40 p.m., squall and heavy rain shower. 2 p.m., dark cloud, slight rain.

June 26. South Kensington, 12.45 p.m., dark cloud, slight shower. 12.50, heavy shower. 5 p.m. heavy cloud passing from west, rain at 5.10.

One of the traces, viz. that of February 22 (Fig. 7), is obviously suggestive of atmospheric waves, but we have no observations to connect them with a succession of banks of cirrus-cloud or any other periodic phenomena that occur from time to time, nor have we any information as to the direction or speed with which the barometric waves were travelling.

The barometric traces of the showers are very different in the details of shape, but in all except the remarkable trace during the phenomenal darkness between 10 and 10.30 a.m. of May 27 (Fig. 4), and the striking peaks of June 25 (Fig. 10) and July 2 (Fig. 6), a sudden increase of pressure followed by a gradual relapse is shown. In the exceptional cases the relapse is as sudden as the rise.

The process closely watched was as follows:—The pen began to rise when a dark cloud began to pass over; as the darkness increased the pen continued to move upward. With maximum darkness the highest point of the trace was reached. Rain then began to fall, and the pen gradually recovered its position, light at the same time returning. Speaking generally, if the rain was copious, the relapse of pressure was gradual; if only a few drops fell from the passing cloud, the relapse was rapid as the cloud passed and the light returned. The most striking instance was that between 10 and 10.30 a.m. on May 27, which was carefully watched. On that occasion there were thunderstorms at Oxshott, at Rickmansworth, and in various other localities, but no thunder was heard

or lightning seen at South Kensington. It became phenomenally dark, and while the darkness was coming on the pen visibly rose. Although the cloud moved rapidly to the northward, there was no surface wind but a portentous stillness. At the peak of the curve light began to come under the canopy from the south, and illuminate the south side of the chimney stacks; a few drops of rain fell, and the whole cloud passed away, leaving a barometric trace remarkably symmetrical.

The same general process was followed in every case, although the differences of detail are sufficiently obvious.

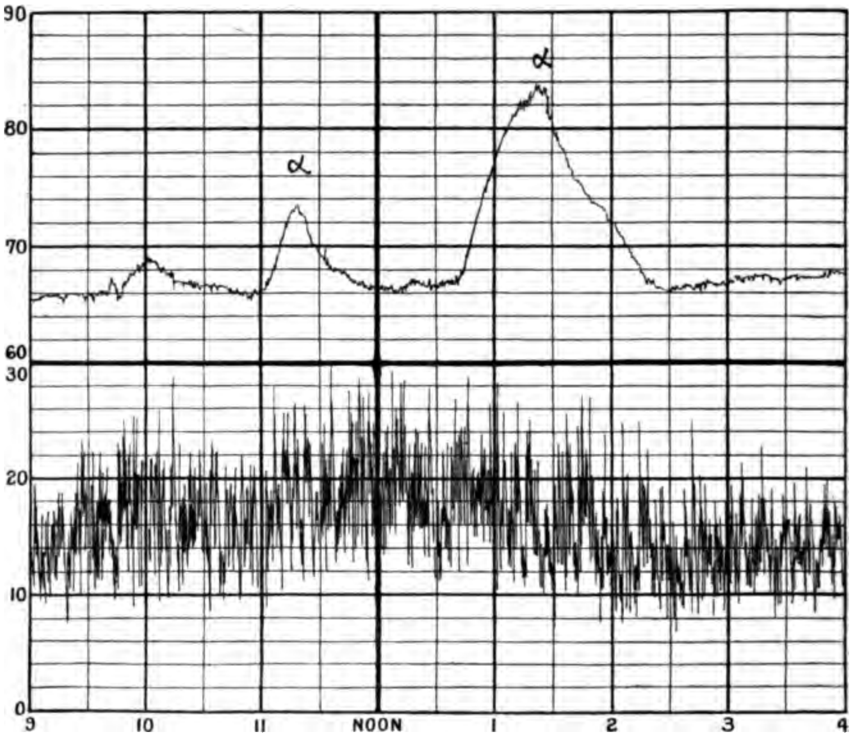


FIG. 13.—Wind and Snow-showers at Oxshott, November 22, 1904.
a, Snow-showers.

The general similarity in the type of barometric change associated with summer showers points to its being the effect of some general cause. It is clearly not to be accounted for by supposing the shower to represent the rain area of a small, or secondary, depression, for the barometric change is a sudden rise of pressure before rainfall commences. Hence, although passing showers are characteristic of an isobaric distribution which displays secondary depressions some further explanation of the peculiar barometric changes must be sought.

To what extent electrical action may be regarded as a cause is not known. The showers are in many respects analogous to thunder-showers, when there is conspicuous electrical display, and it would be interesting

to compare the traces with an electrograph record, so arranged, if possible, as to give a continuous trace during the shower. Here we propose only to offer a few remarks on the possible mechanical effects of the condensation of water vapour, the cause which was numbered 5 on page 47.

The suggestion of such effects arises from the fact that it is while darkness is increasing and the cloud is presumably thickening, without rain falling, that pressure increases with marked rapidity. When rain begins to fall, the pressure begins to fall too. The circumstances are exceedingly complex, and it may be impossible to disentangle the separate events, but, speaking generally, when the cloud is forming the air which carries it is rising *because it is pushed upwards by colder air taking its place.* The rising air is cooling *because it is expanding under diminishing pressure.* The amount of expansion depends upon the pressure of the expanding mass. The column of air over any darkened region has to carry the weight of the condensed drops, which do not add to the elastic force of the air in which they are formed. They would, however, increase the pressure at the surface (because they must be taken into account in computing the whole weight over an area), unless the air beneath them were pushed from underneath by the gradually increasing aggregate weight of the falling drops. To follow out the suggestion further we will now suppose—(1) that the mass of air in which the changes are taking place is travelling and not stationary; and (2) that we have to deal with a linear cloud of considerable dimensions. The distribution of thunder-showers on May 27, for example, suggests that the advancing cloud may have extended from the east of London on the one side to beyond Oxford at least on the other. Also it might be, say, 10 miles broad.

The linear extension of the cloud makes the consideration simpler, because the air to be pushed from under the cloud by the weight of the suspended drops must pass out either forwards or backwards: lateral motion may be left out of account. We have a further complication, however, from the fact that the wind aloft in the cloud-level is greater than that at the surface. It would follow that if the distribution of velocities were suitably adjusted, the extra pressure due to the weight of the drops might push the lower layers forward so that the advancing edge did not gain upon, but simply kept pace with, the advancing cloud. In such a case an increase of pressure would travel with the cloud-carrying wind, advancing with a species of wave motion; but the shape of the wave of pressure would always be modified by the extent to which the condensed drops were falling out on the one hand, or being formed on the other hand.

Many different magnitudes would have to be considered before such a suggestion could be tested for any special case, but it may be remarked that the relation of the pressure changes experienced at any station to the rainfall at that station does not furnish a test.

It is the rain remaining in the air, and not that which has fallen out of it, which is suggested as causing pressure changes. The hundredth of an inch of mercury pressure would imply at least enough raindrops above the station to give ·14 inch of rain, but where the drops would fall and the rain in consequence be measured is another matter. It is interesting to note that during the phenomenal darkness experienced about 10.15 a.m. on May 27 in South Kensington, when there was no thunder

and hardly any rain, the pressure fell as the cloud passed away very much as it rose when the cloud came on; but at Oxshott, where there was a thunderstorm, there is no similarity between the rising and falling sides of the curve. Again, on July 2, when there was a little explosive shower, with hail, there was also, as shown on the trace of No 1, a rapid rise for a few minutes, succeeded by an equally rapid fall.

It may perhaps be urged against the suggestion of the weight of water-drops as a cause of the fluctuations, that the fluctuations corresponding with the snow-showers of November 22 (Fig. 13) were much larger than those of the summer thunder-showers; this makes it still more desirable to endeavour to trace a connection between the fluctuations and the electrical condition of the atmosphere.

We have noted only a few of the points of interest arising directly from a study of the traces that have been obtained hitherto, and it is clear that comparative readings at stations sufficiently close to enable us to trace the changes in recognisable disturbances are essential for the adequate study of the questions which arise.

The curves obtained by this instrument show clearly at least two kinds of small fluctuations, viz.—(1) the periodic variations represented in the trace of February 22; and (2) the non-periodic disturbances corresponding to summer showers enumerated on p. 47, or the snow-showers shown in Fig. 13.

In order to trace the time relations as well as the meteorological relations of these variations, it is necessary to have at least three stations suitably distributed, and to note the meteorological conditions attending the occurrence of the passing disturbances. More stations than three would be advisable in order to make a complete investigation.

Without further inquiry, no satisfactory opinion can be formed as to the distance apart at which the stations should be for the examination of different classes of phenomena, and in order to carry the subject further it is desired to enlist the co-operation of those Fellows of the Society who are willing to provide themselves with a Micro-barograph of comparable form, or to take charge of an instrument, if means can be found for providing one. It is not necessary that the instruments should all be of the same pattern as that described in the paper, but there are great advantages attending the use of a uniform time-scale. Any one willing to take part in this investigation should communicate with one of the authors.

APPENDIX.—Calculation of the Scale of the Instrument.

Suppose a cylinder of external radius b, and internal a, to be closed at one end, and to float mouth downwards in mercury. Let the external pressure (expressed as a height of mercury) be P and the internal p. Let the top of the cylinder be at a height x above the external mercury-level, and suppose $P = p - y$ where y is small compared with P, p, or x.

The external mercury-level cannot be altered by any change in P or p, since the altered displacement of the float is exactly compensated by the change of the mercury level inside. This follows from the fact that the floating weight is constant, and therefore the total displacement is

invariable. Hence δx will denote the change in height of the cylinder.

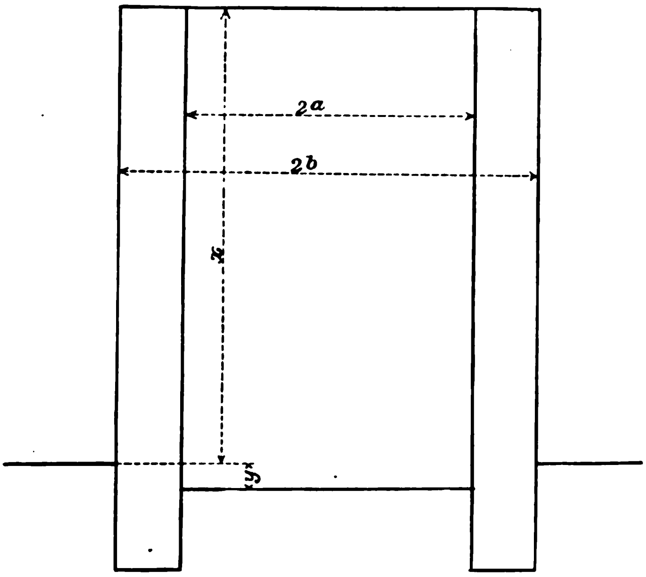


FIG. 14.

We have, assuming constant temperature—

$$\pi a^2(x+y)p = \text{constant} \qquad \text{I.}$$

$$P = p - y \qquad \text{II.}$$

$$\pi a^2 \delta y = \pi(b^2 - a^2)\delta x \qquad \text{III.}$$

From I. $\quad x\delta p = -p(\delta x + \delta y),$

$y\delta p$ being neglected.

Hence

$$\delta P = \delta p - \delta y,$$

$$= -\frac{p}{x}\delta x - \frac{p}{x}\delta y - \delta y,$$

$$= -\left\{\frac{p}{x} + \left(1 + \frac{p}{x}\right)\frac{b^2 - a^2}{a^2}\right\}\delta x.$$

Of these quantities, p is very nearly the atmospheric pressure, since the leak prevents y from exceeding $\frac{1}{40}$, or at the outside $\frac{1}{20}$ of an inch. Considerable variation must occur in p, and hence the scale cannot be always the same. Putting $p = 30$ in., which is not far from the sea-level average, we can choose x and the ratio $b : a$ to give any desired scale. Take $x = 60$,

$$\delta P = -\left\{\frac{1}{2} + \frac{3}{2}\frac{b^2 - a^2}{a^2}\right\}\delta x.$$

Further, take $\delta x = -\frac{1}{2}\delta P$, and let the arms of the lever be in the ratio of $40 : 1$, so that the scale may be twentyfold the natural scale, then—

$$\frac{3}{2} = \frac{3}{2}\frac{b^2 - a^2}{a^2},$$

$$b^2 = 2a^2,$$

$$b = a\sqrt{2}.$$

It is immaterial whether the air reservoir be actually over the mercury, or there be a small space only over the mercury, communicating by a small pipe with an external reservoir; but in this case a trifling correction will be required, since equation III. is not strictly correct.

It is easily seen that, with the sizes taken above, the percentage variation of the scale is about half the percentage variation of p. Since p may vary by 5 per cent, the scale may vary by $2\frac{1}{2}$ per cent.

DISCUSSION.

THE PRESIDENT (Capt. D. WILSON-BARKER) expressed the congratulations of the Society to Dr. Shaw and Mr. Dines on the completion of their ingenious instrument for recording the minute waves passing through the atmosphere. The authors had taken much trouble over the instrument and the paper, and were asking for the co-operation of the Fellows to carry on the work. No doubt many would be pleased to take part, especially as most interesting and valuable results were likely to arise from a co-operation of observers.

Mr. J. E. CLARK noticed that the summer showers were clearly shown on the curve. The traces reminded him of the variations in the barometer curves caused by tornadoes in America, and also by whirlwinds, although of course on a smaller scale. He remembered the case of a whirlwind in York in 1892, which made such minor fluctuations on the barometric curve, and he had been interested in such phenomena since. It was also of great interest to notice the speed with which these little disturbances travelled. Referring to the darkness on May 27, he had looked to his own notes for that date, and was able to confirm that the same dark period was experienced at Finsbury Square as at South Kensington, starting in the former place at 10.15 a.m., some time after a thunderstorm, and lasting till 11.15.

Dr. R. H. SCOTT remarked that the Society was to be congratulated on receiving such a valuable paper. It was exceedingly interesting to notice the connection between the various phenomena and the movements of the atmospheric waves, and how the passage of each shower seemed to be shown by the instrument. Some 30 years ago Mr. E. O. Whitehouse had experimented on the same lines, and by using large barrels, which allowed the air to pass freely in and out, attempted to show that waves occurred previous to a storm (*Proc. Roy. Soc.* **19**, 1871, p. 491). At Geldeston, Norfolk, there is a large disused well on a farm,—tenant, Mr. E. T. Dowson,—from which air is blown out during a falling barometer, but flows in again when the mercury rises.

Mr. W. H. DINES said he was inclined to think that the variations of pressure were due to electrical action rather than to any gravitational effect. If two neighbouring places could be subject to a difference of ·01 in. of air-pressure, and there were no compensating force to maintain the difference, a wind of 16 miles per hour would shortly be blowing from one to the other. With a difference of 0·4 in., the corresponding wind would amount to a gale. It was impossible for gravity to have any horizontal component, and hence one must fall back on electrical action, since the dynamical effect of the earth's rotation, though fully capable of maintaining a steep gradient over a large area, was plainly inadmissible in the present case.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 16, 1904.

Ordinary Meeting.

Capt. D. WILSON-BARKER, F.R.S.E., President, in the Chair.

GEORGE WILLIAM CHILVERS, 59 Stile Hall Gardens, Chiswick, W. ;
GEORGE MUIRHEAD CLARK, Assoc.M.Inst.C.E., Johannesburg, Transvaal ;
Rev. JOSIAH NELSON CUSHING, D.D., F.R.G.S., Rangoon, Burma ;
CHARLES DALES, Nelson Road, Bournemouth ;
WILLIAM BURLISTON-ABIGAIL DINGWALL, Matehuala, Mexico ;
JAMES HERMANN FIELD, B.A., B.Sc., Simla, India ;
CECIL BRAHAM GOODYER, Levenshulme, Manchester ;
JOHN SMITH HILL, B.A., B.Sc., Aspatria, Cumberland ;
EVAN LEWYS LLOYD, M.R.C.S., Towyn, Merioneth ;
THOMAS MIDGLEY, 45 Hastings Road, Bolton ;
GEORGE FRANKLYN NIGHTINGALE, Daventry ;
GEORGE PAUL, 32 Harlow Moor Drive, Harrogate ;
ROBERT WILLIAM SMITH, Jun., Cahir, Co. Tipperary ; and
CLEMENT H. TIMMLER, Fort Jameson, Rhodesia,
were balloted for and elected Fellows of the Society.

The following communications were read :—

(1) "METEOROLOGICAL OBSERVING IN THE ANTARCTIC REGIONS." By Lieut. CHARLES ROYDS, R.N. (p. 1).
(2) "DECREASE OF FOG IN LONDON DURING RECENT YEARS." By FREDERICK J. BRODIE, F.R.Met.Soc. (p. 15).
(3) "HURRICANE IN FIJI, JANUARY 21-22, 1904." By R. L. HOLMES, F.R.Met.Soc. (p. 29).

December 21, 1904.

Ordinary Meeting.

Capt. D. WILSON-BARKER, F.R.S.E., President, in the Chair.

W. H. CHAMBERS BULLEN, 20 Pagoda Avenue, Richmond, Surrey ;
HAROLD ANTOINE DES VŒUX, M.D., 14 Buckingham Gate, S.W. ;
RUDOLF G. K. LEMPFERT, M.A., 63 Victoria Street, S.W. ; and
ROBERT MELBOURNE MACFARLAINE, Bombay, India,
were balloted for and elected Fellows of the Society.

Mr. F. GASTER and Mr. T. P. NEWMAN were appointed Auditors of the Society's Accounts.

The Discussion was taken on Mr. F. J. BRODIE's paper, "DECREASE OF FOG IN LONDON DURING RECENT YEARS" (p. 15), which had been postponed from the last Meeting, after which the following paper was read :—
"THE STUDY OF THE MINOR FLUCTUATIONS OF ATMOSPHERIC PRESSURE." By W. N. SHAW, D.Sc., F.R.S., and W. H. DINES, B.A., F.R.Met.Soc. (p. 39).

CORRESPONDENCE AND NOTES.

Conference of Directors at Innsbruck, September 1905.

The following letter has been received by the President of the Royal Meteorological Society from the Secretary of the Meteorological Office :—

"Dear Mr. Bentley—Professor Hildebrandsson, of Upsala, Secretary of the International Meteorological Committee, has reminded me that it is proposed to hold a Conference of Directors and Superintendents of Meteorological Institutes and Observatories at Innsbruck, in September of the current year.

"He desires to know what date will be convenient for those English meteorologists who desire to attend; and he also asks that English meteorologists shall send to him any subjects that they wish the Conference to discuss.

"I shall be glad if you will bring his requests before the Fellows of the Royal Meteorological Society in any form that you think appropriate.—Believe me, faithfully yours, W. N. SHAW.—January 24, 1905."

Freezing of the Wet-bulb Thermometer.

Meteorological observers, as a rule, experience considerable difficulty with the Wet-bulb Thermometer when the temperature of the air is below 32°, owing to the muslin and conducting thread becoming frozen, and so needing special attention. Sometimes the muslin will become frozen directly the Dry-bulb reaches 32°, while occasionally the freezing will not take place until the temperature has fallen 2° or 3° lower.

At 8.10 a.m. on November 23, 1904, I found the muslin and conducting thread on my Wet-bulb Thermometer to be *unfrozen*, although the temperature of the air was 6° below the freezing-point. The actual readings of the thermometers were—Dry-bulb 26°·0, Wet-bulb 24°·6.

Immediately after touching the conducting thread with my glove both the thread and muslin became frozen, and the mercury in the Wet-bulb forthwith ran up to 32°.

It would be interesting to know whether other observers have ever noticed the muslin and thread on their Wet-bulb Thermometers unfrozen at as low, or even lower, temperature than the above, 26°·0.

Since the above was written a remarkable instance has occurred of the freezing of the muslin and thread on the Wet-bulb Thermometer when the temperature of the air was nearly 3° above the freezing-point.

At 9 a.m. on January 15, 1905, the readings were—Dry-bulb 34°·6, Wet-bulb 29°·4. The muslin and conducting thread were completely frozen. There was a strong wind blowing at the time, the direction being East, force 6.—WILLIAM MARRIOTT.

Infirmary Meteorologist.

In consequence of the disestablishment of the Ben Nevis Mountain Observatory and the liberation of the attendant observers, I beg to offer a suggestion that meteorological stations might be installed at the Royal Infirmaries, with an observer and caretaker attached to each.

Such office seems now seriously to be called for in consequence of the great increase of the Infirmary buildings and air spaces intermingled, but more than anything else by the introduction of the modern method of treatment of certain complaints by the open air exposure. It would be important for the physician in such cases to get an early intimation of change of weather, and prospect of storms and rains interfering with the success of the open-air treatment adopted.

Information of the weather from places outside the town is now of little use in large cities, which now have a special climate of their own, independent

of the country. The hospital meteorologist would require to make his own observations locally and use independent instruments and experience. He might go round all the local instruments, wherever installed, every morning and draw up a form of report, have it submitted to a committee or secretary, and thereafter post it up in the hall for general information of the officials and the hospital staff.

It would be important to know daily the temperatures of each pavilion, both inside as well as outside; and a self-recording wind-vane, with index and card, would have to be established, and the card exhibited ready every morning for inspection in the hall, to indicate the presence of the East winds or not.—W. G. Black, F.R.C.S.E., 2 George Square, Edinburgh.

Two Cases of Lightning-Stroke, July 17, 1903.

At the Annual Meeting of the British Medical Association at Oxford in July 1904, Mr. J. Lynn Thomas, C.B., F.R.C.S., Surgeon, Cardiff Infirmary, read the following interesting paper on "Two Cases of Lightning-Stroke," which was printed in the *British Medical Journal*, October 29, 1904. The manager of that journal has courteously placed at our disposal the blocks of the illustrations.

On July 17, 1903, two men belonging to the National Telephone Company were at work on the main road between Llanishen and Whitchurch when a severe thunderstorm with torrential rain came on; they took shelter under a large elm tree close by in a lane leading to a farmhouse. They were seen sitting by a friend of mine in a position shown in Fig. 1 a few seconds before they were struck by lightning. They were brought to the Cardiff Infirmary in an unconscious state, and remained under my care until they were convalescent. One of them was burnt, and had his clothes and boots torn off to the extent shown in the photograph of a dummy dressed in his clothes (it is on view in the Pathological Museum). The other man had no visible injury to his body and clothes, but had fracture of the base of his skull and hæmorrhage from the left ear.

Before describing the course and the local physical effect of the lightning, I will confine my remarks to the more purely medical aspect of the cases.

1. The burnt man (marked *A* in Fig. 1) had his clothes torn off down the back, and was found practically naked in the lane, lying on his right side, groaning loudly, motionless, and was damming up the rain-water into a pool (marked *A* in Fig. 3). The lightning entered the body by boring a hole through the brim of his cap (see photograph), and then removed a ½-in. strip of hair from that point vertically to the nape of the neck. The scalp under the removed hair was quite smooth; there was no evidence of singeing or burning, and it looked as if the hair had been gouged out by an exquisitely sharp instrument. On the nape of the neck there was a narrow brownish longitudinal line of discoloration for about 1 in. before the lightning current spread out into the burnt areas. The burns were mostly of the second and third degrees, and it is worthy of remark that the hollow over the spine escaped injury owing either to the current sparking across the gap or to its being conducted across by the shirt, which at the time was soaking wet. The burns on the ankle and sole of the right foot—the points where the current passed out—were more serious, the skin being irregularly torn, everted, and showing numerous punctiform scorches, suggesting violent egress through innumerable pin-point apertures of intensely hot electrical current. The face, front of the body, scrotum and penis, one arm, and both forearms had no burns.

2. The man marked *B*, who had no burns and no injury to his clothes, is of interest when discussing the cause of hæmorrhage from the ears, and also of the purely mechanical action of lightning upon the two men.

The Nature of the Lesions in the Tympanic Membranes.

The man who had superficial burns had slight hæmorrhage from both ears. There was no perforation in either ear. The umbo and its immediate surroundings were intensely congested and ecchymotic when first examined, six days after the accident. It is very likely that there were minute holes in the tympanic membranes, like the ones that are made by the spark of an induction

FIG. 1.—Position of men *before* being struck by lightning.

coil upon a thin sheet of paper when held between the sparking points. The umbo being the most prominent point of the tympanic membrane in the tube of the external meatus, would, according to laws of electricity, be the point to take the intensest action in the condition of electrical currents in entering or leaving the drum ; the action of such an electrical current would, I think, explain the condition found in the tympanic membranes. The appearance of the left tympanic membrane in the case that had no external injury showed a rent with coagulated blood near its periphery in the upper half of the tympanum ; there was no evidence of injury to the umbo, and as the man had

undoubted signs of fracture of the base of his skull through the petrous portion, I am inclined to believe that the fracture was the cause of the injury to the tympanum and not the lightning current.

My friend, Mr. Arthur Cheatle, King's College, London, has kindly given me the following references to injuries of the tympanic membranes due to lightning-stroke: *Transactions of the Otological Society*, vol. 3, H. Macnaughton

FIG. 2.—Clothes of man marked A struck by lightning.

Jones; "On a Case of Double Perforation of the Membrana Tympani, the Result of being Struck by Lightning," Hinton's *Aural Surgery*, p. 124 (1874).

The relative position of the two men before and after being struck by lightning is of interest (see Figs. 1 and 3), and in order to demonstrate as clearly as possible the course of the track of the lightning I photographed the tree with two men sitting in the position the patients were in when seen a short time before they were struck.

The irregular slopes of the ground round the trunk of the tree at the spot at which they sat lends itself naturally to assuming that the above position is the most natural one under the circumstances.

E E^1 are marks on the tree facing east where part of the lightning escaped by blowing away the bark.

A A^1, the man who was burnt by the lightning entering through his cap and scattering his clothes in different directions, fragments of which were found on the branches at *C*, 11 to 12 ft. away.

B B^1, the man who was not burnt and was subsequently found insensible at B^1 (Fig. 3).

X, bush which contained a bird's nest with young ones, and is in the direct course the man *B* must have travelled when thrown. Had he struck this bush in his flight the young birds probably would have been thrown out of the nest. They escaped unharmed.

One of the roots of the tree partially stripped of its bark passed obliquely in the interval between the men and partly under the left thigh of the man *B* to the lane.

On the opposite side of the lane where the lightning went to earth was a hole 2 ft. in diameter about 16 ft. from the men *A* and *B*.

The circumference of the tree at *E* is 8 ft. 6 in.

The lightning struck a branch of the tree near the top on its west aspect, and its track could be followed to the point *E*, where an exceptionally large piece of bark was blown away; part of the current then pierced the cap of the man *A*, and travelled down his back and right lower limb, burning the skin the whole way, and finally passing out by tearing the boots and blowing some of the nails away; another part of the current passed along a root of the tree which was situated between the two men, and partly under the left lower limb of the man *B*. Then the lightning crossed the hard smooth surface of the lane, and went to earth at a point 16 ft. distant by boring a 2-ft. trumpet-shaped hole in the soil. There was no evidence of intense heat in the soil.

The man *A* was found at A^1, a distance of about 3 ft., a few minutes after the accident, by a farm labourer, who was within 50 yards of the spot. He was motionless, "lying on his right side, nearly stark-naked, and groaning; you could have heard him miles off." He was carried into the farmhouse about 60 yards off, and when they returned to inspect the spot the farmer's wife noticed the boots and legs of the man *B* over the low hedge at the point B^1. He was "all of a heap, as if dead, with legs up in the air."

The distance from *B* to B^1 is about 11 ft. Hanging on to branches of the tree at *C* about 10 ft. above the ground in the same direction and about the same distance as the man *B*, were fragments of the clothes of the man *A*.

The mechanical force which shifted the men was an accompaniment of the lightning, and passed between the two men and partially inside the clothes of the man *A*. The burnt man was shifted at least a yard in a northerly direction, the other one, about whom the evidence is more exact, being hurled at least 11 ft. in an opposite southerly direction, together with the other man's clothes. The probability is that the latter was hurled up into the air and fell in the posture he was found in, lying on his face on sloping ground with his legs flexed at the knee, his feet up in the air and nearest to the spot whence he came. The chances are that he would have thrown the young birds out of the nest in the bush *X* had he travelled near the ground. The fracture of the skull may be due to either (*a*) a fall on his head—against this view is the fact that the ground he fell on was fairly soft—or (*b*) due to his head striking the trunk or a branch of the tree; (*c*) due to the mechanical force of the lightning itself—this would have to operate either from above on the vertex cranii or from below through the occipital condyles.

What the exact nature of the mechanical power which accompanies the electrical current of lightning is, we do not know; but it has been suggested—

Firstly, that some of the phenomena can be explained by sudden evolution of

steam, due to the action of intense heat upon water in the wet clothes; but the beautiful experiment of Sir Wm. Crookes, by which he demonstrated the

FIG. 3.—Position of men *after* being struck by lightning. ——> . . . . . ——> Track of lightning.

mechanical power of infinitesimally small electrical currents *in vacuo*, makes one ponder what can be the true explanation of the mechanical power of the mighty

electrical current of lightning under ordinary atmospheric pressure, and travelling at almost incomprehensible speed.

Secondly, a simpler factor in the possible cause of removal of the two men on receiving a powerful electrical shock whilst in a sitting posture is that of muscular action. All the muscles might, upon the receipt of stimulus from lightning current, suddenly contract, with the result that the men would involuntarily jump to a considerable distance from the spot where they sat. Against such a view being the right one is the fact that the direction taken by the men in opposite directions would not tally with what one would expect from such muscular action. Had the men been found in the lane in front of the spot where they sat, such an explanation would be tenable, but the fact that fragments of the clothes of the man A were found at C, having been blown in the same direction as the man found at B^1, points to the generation of a common disruptive force taking place somewhere in the interval between the two men.

Thirdly, local earthquake might possibly be evolved by the action of lightning going to earth, and a sudden violent upward movement of the soil in the area between them would, under such conditions, possibly account for their displacement. This view is negatived by the absence of disturbance of the soil, and also by the absence of fissures or cracks in the surface of the lane, which, as has already been mentioned, was hard and smooth, and would have cracked had there been sufficient uprise of the ground to throw the men to the places where they were found.

Lastly, sudden compression or condensation of the atmosphere at right angles to the direction of the path of the lightning would explain all the circumstances of the conditions found. We know of the existence of such atmospheric waves preceding and also accompanying the flight of bullets in the air, and it is quite reasonable to suggest that mighty waves of enormous potentiality under certain conditions are generated round the path of lightning current, and might be strong enough to blow objects in the immediate vicinity of their course to a great distance.

In this particular case such a force would act more forcibly upon the man B than the man A, owing to the existence of a larger volume of air existing between the man B and the electrical current than between it and the man A, with whom it was in almost immediate contact.

I think it is difficult to assume that sudden generation of steam to such a degree as to be able to displace the men could take place without showing scalding effects upon the exposed parts of the head and hands of the two men, and especially in the hollow over the spine of the man A.

A Legal Decision as to Damage by Lightning and Wind.

In a periodical published by the University of Dijon we find an interesting decision by the civil tribunal of that city, relative to responsibility for damage done by lightning and wind. A few years ago we published a decision of the United States Circuit Court of Appeals (*Monthly Weather Review* for December 1900, p. 550) to the effect that forecasts of local rain have not yet attained such commanding respect by reason of their accuracy as to justify us in holding shippers guilty of culpable negligence if they do not provide against damage from heavy rains when light local showers are predicted. "The case of local rains is different from that of storms of great violence, whose existence, course, and time of arrival are publicly announced by signals which the master of a vessel is bound to observe."

With regard to the case on trial before the court at Dijon, the record shows that on June 30, 1901, at about 6 p.m., after a day of exceptional thunderstorms, an extremely violent wind occurred, producing great destruction. Besides the destruction due to the wind, many cases were found in which the

damage was undoubtedly due to lightning. Public opinion and the local press attributed everything to the passage of a tornado. The work of destruction was accomplished in a few moments, and was followed by a heavy fall of hail over a large area, after which occurred an exceptionally heavy rain. The administration of the docks of Burgogne attributed a certain damage to lightning, and demanded that the repairs should be made by the nine companies in which they were insured; but, on the contrary, the insurance companies maintained that the disaster was equally attributable to the wind, and that, according to their policies, they did not insure in any manner against damage done by "hurricanes or cyclones, tornadoes, or any other meteorological or electrical phenomenon, except thunder and lightning."

In the trial before the judges the facts of the disaster, the wind and the lightning, were abundantly established. Then came a large mass of testimony relative to phenomena observed in Europe and America in connection with thunderstorms and tornadoes. Written or printed documents were presented from about twenty meteorologists, including Professors Alexander G. M'Adie and Alfred J. Henry of the Weather Bureau. Considerable time was given to the study of analogous cases of destruction by other tornadoes, such as that of Monville, August 19, 1845; St. Claude, August 19, 1890; and an elaborate study was made of the destruction in the present case—Dijon, June 30, 1901—most of which was evidently due to wind. After three days of pleading the civil tribunal of Dijon finally rendered the following judgment on the 1st of July substantially in accord with the opinion of two of the three experts, namely, Galliot, Engineer-in-Chief of Bridges and Roads; Pigeon, Professor in the Faculty of Sciences at the University of Dijon; and Julien, civil engineer in Paris:—

"Notwithstanding the uncertainty of the experts, who have been unable to determine with exactness the amount of destruction due to lightning on the one hand, and that due solely to the violence of the wind on the other hand, it is nevertheless possible for the Court to pronounce the opinion that it is certain, according to the testimony of the experts, that the lightning and the wind acted almost simultaneously; that it is also certain that if the lightning, striking the building *M* and the shed *N*, had not produced in these two structures a weak point, as is shown by the partial destruction of the boards and framework, that the wind would not have had force enough to demolish these two buildings, as was done; that the proof of this fact is also shown by that other testimony that the building *M* and the shed *N* are the only ones injured in the neighbourhood of the docks. Other buildings, more or less important and of construction more or less unsubstantial, have suffered no damage, except, perhaps, some tiling displaced, such as the shed at the right of the principal entrance, on the boulevarde Voltaire, and the small administration building just opposite the entrance gate, which were not touched. It must therefore be concluded that the lightning-stroke and the violence of the wind, by their combined action, had an equal part in the disaster, from which it follows that the responsibility for the disaster should be attributed one-half to the lightning-stroke and one-half to the violence of the hurricane. . . .

"Considering that the insurance companies have stipulated, in the general conditions printed in their policies, that the insurance covers only damage by fire resulting from lightning, but that, in consideration of a special premium, they are accountable for damages other than those by fire resulting from the stroke or explosion of lightning (the insurance against lightning not including in any case the damage caused by hurricanes, cyclones, tornadoes, or any other meteorological or electrical phenomenon other than thunder or lightning): Considering, nevertheless, that by a manuscript clause which is found in all the policies, the company gratuitously makes payment for damage that the stroke or

explosion of the lightning, when duly attested, did or could have done to objects insured by the present policy, even when fire does not result:

"Considering that it results with certainty from the stipulations above, that the companies are responsible for damage other than fire directly due to lightning-stroke:

"Considering that it has been shown that the cause of the damage occasioned to the buildings and merchandise of the docks was due by one-half to the lightning-stroke; that it is therefore this part which should be borne by the insurance companies and divided among them according to the proportions stated in their contracts. . . .

"For these reasons,

"The Court, after deliberation in accordance with the law, Declares that the damages caused June 30, 1901, both to the buildings *M* and *N* of the Society of Docks and to the merchandise and contents, are due one-half to the lightning-stroke and the other half to the violence of the wind;

"Declares that one-half of the damage thus caused should be borne by the insurance companies according to the proportions stated in their insurance policies, and with interest from the day of demand."

At the conclusion of this judgment the two parties came together and adjusted this matter.—*Monthly Weather Review*, August 1904.

Speculation in Rain.

At Totnes yesterday, before Judge Lush Wilson and a jury, three members of the committee of the sports and gala held at Paignton on Whit Monday sued a firm of insurance brokers on an insurance policy of Lloyd's, which, it was said, provided that if more than ·08 inch of rain were recorded between nine in the morning and four in the afternoon they would pay the difference between the gate-money received and £100. The judge described the vessel in which the gauging was taken as "very antiquated and open to serious criticism." The gauging was measured with a pencil and ordinary foot-rule to be one-eighth of an inch. The defendants, while not disputing the claimants' *bona fides*, disputed the possibility of such a quantity falling under the conditions described, especially as only ·01 inch was recorded at Torquay, two miles distant. The judge pointed out that the defendants took no steps to ascertain the gauge fall, and a verdict was given for the plaintiffs for £36 : 15s.—*Daily Graphic*, November 30, 1904.

Rain. By P. Lenard. [Translated from the *Meteorologische Zeitshcrift*, June 1904, by Dr. R. H. Scott, F.R.S.]

Although rain has been quite correctly referred to physical principles, its occurrence presents us with many puzzles. Independently of the special process of separation, without which clouds cannot give rain, that difficulty still occurs with the succeeding circumstances which accompany the fall of the water.

A special point[1] relating to this subject has induced me to make experiments and observations on raindrops, of which I proceed to give particulars.

The experiments refer to the behaviour of raindrops in ascending currents of air, which, independently of its own special interest, undoubtedly has an influence during rain, is able to throw light on the descending motion of drops in the air, and which, as far as I know, has not yet been investigated. This is succeeded by observations on the quantitative distribution in size of drops in certain falls of rain.

1. If you desire to find a picture of the process of rain construction, which goes rather far into particulars but yet is generally based on observation, there

[1] This was how far the development of electricity on the disappearance of the liquid surface with rain plays a part in the air, and not only when the rain reaches the ground. (See *Wied. Ann.* Bd. 46, p. 584, 1892.)

are two accounts which will be found useful. The first is developed by Osborne Reynolds [1] and deals with the growth of drops during the fall, and refers it to the difference in rate of fall between large and small drops. The other comes from W. Ferrel,[2] and draws attention to the influence of great upward-moving components of the air, which can keep, under certain circumstances, drops in suspension, and in this way can give rise to special phenomena. In both descriptions the rate of fall of the drops, as depending on their diameter, plays a special part, so that I shall commence by bringing together what is already known, and seek to confirm it by new experiments.

The Rate of Fall of Drops in the Air.

2. In the case of the great velocities of fall presented in the atmosphere, the final velocity is also considered, in which an equality is attained between the acceleration of gravity and the retardation by the resistance of the air. For the magnitude of the latter there are these cases to be considered, which are here distinguished as A, B, and C:—

3. A. Slight velocities, such as occur with very small droplets. Cyclonic movements of the air do not come into consideration; the resistance is due entirely to internal friction in the atmosphere, and is proportional to the full power of the velocity.[3] The constant velocity of fall, in this case, is $v = 2gr : 9\eta$, in which r is the radius of the drop, $g = 981$ (the acceleration of gravity), and η is the constant of friction of the atmosphere, which increases with temperature but is quite independent of barometrical pressure, and is 0·000172 at 0° C. (32° F.). According to this $v = 1270000r^2$,[4] and with those figures the velocities quoted below in Table II. under A have been calculated.

4. B. Greater velocities, such as occur with larger drops. Vortex motion in the air is set on foot, and the resistance is proportional to the square of the velocity.[5] The resulting velocity will be $\sqrt{gr : \gamma d}$, where d is the density of the air at 0° C. (32° F.) and at normal pressure = 0·00129, and γ a constant to be determined empirically for the special case. For this determination we have taken rather large solid balls, which gave $\gamma = 0{\cdot}375$ [6] $- 0{\cdot}188$.[7] I prefer making experiments on rate of fall with water-drops of the radius of 2 or 3 mm. (·08 or ·12 in.), and these give $\gamma = 0{\cdot}153$.[8] According to this $v = 2230\sqrt{r}$, and on this formula the velocities given in Table II. under B have been calculated.

As to the limits between the falls under A and B, I have set it at the size of drops, $2r = 0{\cdot}29$ mm. [·0114 in.], for which both the formulæ give the same velocity, agreeing reasonably with reality.

5. C. This case occurs as soon as the air seriously alters the form of the drops, so that larger drops, as we can see, attain greater velocities. The constant γ for the formula B, which depends on the form of the moving body,

[1] *Mem. of the Lit. and Phil. Soc. Manchester*, 3rd series, vol. 6, p. 48, 1879.

[2] I have not had access to this in the original.

[3] *Cf.* Kirchhoff, *Vorlesungen über Mechanik*, pp. 374 *et seq.*, 1883.

[4] Whenever special units are not given, the C.G.S. system is employed.

[5] See Helmholtz, *Wiss. Abh.* vol. 1, p. 158.

[6] Newton, *Philos. nat. princ. math.* Lib. 2, sects. 2 and 7.

[7] Hutton, *Trans. Roy. Soc. Edin.* vol. 2.

[8] Lenard, *Wied. Ann.* vol. 30, pp. 224 *et seq.*, 1887. Some observations with alcohol drops have been used for the calculation of the value of γ which is given. As a possible explanation of the fact that the constant γ of the air-resistance with water and alcohol drops comes out less than for solid balls, I have (*l.c.* p. 230) assumed slight deformations of the drops, which are certainly not visible in the observations. If this explanation be admitted, they must be formed momentarily, as appears from what is said later on, by the pressure of the air passing by, and must be very slight deformations. These deformations must appear much less frequently in quicksilver drops than in those of water and alcohol, and this shows why the constant γ for quicksilver drops comes out nearly the same as for solid balls (*l.c.* p. 228).

must then lose its value, and further experiments must be undertaken to determine the final velocity.

The Floating of Drops.

6. In order to carry out suitable observations, a large ventilating wheel-fan on a vertical axis was set up in the lower part of a vertical cylindrical vessel, as

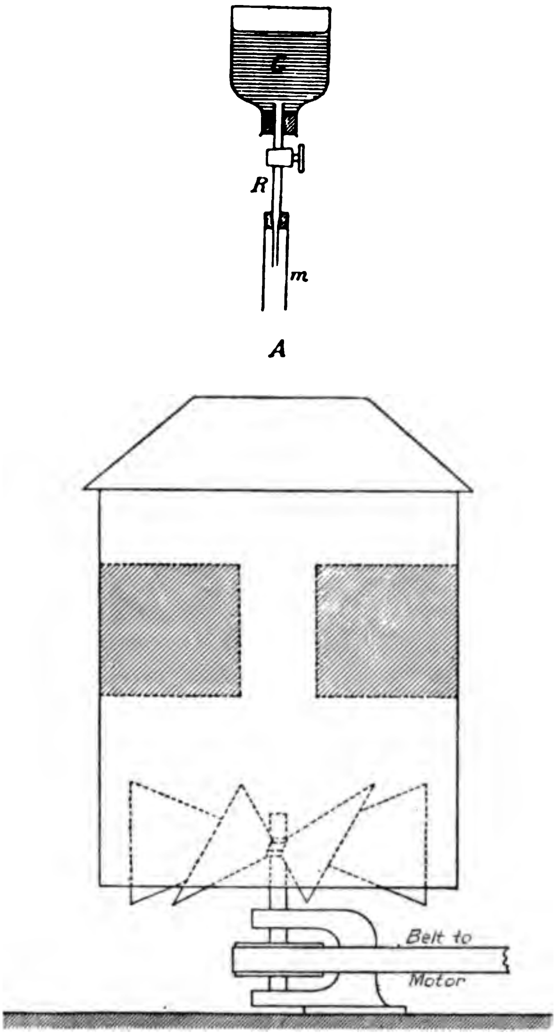


FIG. 1.

shown in Fig. 1. The diameter of the wheel is 65 cm. [25·6 in.], of the vessel 67 cm. [26·4 in.], and its height 100 cm. [39·4 in.]. If the wheel is set in rotation by a powerful electro-motor, a strong current of air is drawn into the vessel from below, and blows vertically upward from it. In order to clear this current from the component of rotary motion it obtains from the wheel as far as

possible, we have placed in the upper part of the vessel six radial screens at equal distances apart, two of which appear shaded in the figure. Finally, a conical cover of tin is put on the vessel, which confines the current to the small section of 42 cm. [16·5 in.], but that allows its velocity to remain constant throughout its area, and even to some considerable height above it.

With this current of air drops of water can now enter from the vessel *C* through the tube *R*. In order that the formation of drops may go on without hindrance, the mouth of the tube *R* is surrounded by a sheath *m*, so that the air inside it is at rest. Drops of different sizes may be produced by varying the diameter of *R*; and by regulating the ventilation it is easy to bring the drops to floating. We then see the drops, after they leave the opening of *m* with slight velocity, sink and come to rest about *A* in the figure, about 50 cm. [19·8 in.] above the opening of the cone. It remains there floating until finally, moving slowly laterally out of the current, it comes to spots of lower velocities and then falls near the apparatus. The floating lasts from two to four seconds. As the floating drop may be followed by the eye, it may be caught on blotting-paper when it finally leaves the current.[1] In order to measure the air velocity at the point, a small cup anemometer was introduced at the spot where the floating occurred.[2]

The smallest drops were not allowed to fall into the current alone, but in the form of a stream which gave a swarm of floating drops. The stream was then checked until the swarm had cleared itself by the fall of drops, and then finally the drops which remained floating longest were dealt with as is indicated.

7. The results obtained, arranged in groups according to size of drops to yield mean values, are given in the first two columns of the subjoined table. In the third column we give, for comparison, the velocities given by formula *B*.

TABLE I.

Diameter of Drops.[3]		Velocity of Air in Floating Drop = Fall Velocity in Calm Air.			
		Observations.		Calculated on *B*.	
in.	mm.	m. per sec.	miles per hr.	m. per sec.	miles per hr.
·050	1·28	4·8	10·74	5·65	12·63
·137	3·49	7·37	16·51	9·3	20·80
·177	4·50	8·05	18·01	10·6	23·71
·215	5·47	7·98	17·85	11·7	26·17
·251	6·36	7·80	17·44	12·6	28·18

We see from these figures that as the drops increase the velocity soon reaches a limit very nearly 8·0 m. per second [17·9 miles per hour], above which it does not rise; in fact, if the size of the drop increases, it diminishes a little. In all cases the velocity is less, and therefore the real air resistance is greater than what corresponds to the fall *B*. The difference is very considerable with the largest drops, but is quite perceptible with drops of about 1·3 mm. [·051 in.]

[1] This process of drop measurement was, as I discovered subsequently, formerly employed by Professor Weisner, to whose paper I now draw notice (*cf.* 14 also) ("Beiträge zur Kenntnis des tropischen Regens," *Sitzungsber. der k. Akad. der Wissensch. zu Wien*, *Natur. Wiss. Classe*, vol. **104**, Abt. I. p. 1397, 1895). In this paper there are observations of the fall of drops, with the result that drops of the weight of 0·01–0·25 grams [·054–·385 grains] (from 2·3–8 mm. diameter [·08–·315 in.]) with falls of from 5·5–22·2 m. [2·1–8·74] fall with approximately equal velocities of nearly 7 m. per second [15·66 miles per hour]; but always the resistance law *B* is found true, which makes the final velocity proportional to the square root of the drop diameter. The required correction of this contradiction, and a refinement of the result from the nearly constant final velocity, will be found below (7, 8, 9).

[2] The axis of the instrument was to be kept horizontal. Special experiments have shown that when the axis is either horizontal or vertical in a constant horizontal curve, the readings are the same. The table of corrections from the instrument was checked by rotation in calm air and found correct, as the figures given below show.

[3] These are always to be understood as the diameter of spheres having the observed volumes of the drops.

diameter. This is remarkable, as the constant γ of the formula B has been obtained by experiments with water-drops (see 4) whose diameter comes quite within the limits of Table I., and whose velocity, according to accurate time measurements, exceeds 6 m. per second [13·42 miles per hour], so that the drops without experiments are practically in exactly the same relative motion of the air as in the present experiments.

Deformations.

8. A solution of this contradiction comes out from a careful observation of the floating drops. It will be seen that these are much deformed. The deformation consists in the flattening out of the drops in a vertical direction; it increases with the largest drops until they break up. Similar deformations have been noticed by me with the drops of some rain at night when illuminated momentarily.[1] The drops of the earlier fall experiments did not exhibit such deformity. We must therefore conclude that the development of these deformations requires more time than was available in those older experiments, which were only a few tenths of a second. Corresponding with this, the breaking up of large floating drops, which is always preceded by deformation, always occurs after a continued sojourn of the drops in the air inductor.

The requirement of time is intelligible if the deformation is not due to the action of pressure directed normally to the surface of the drop, but is due to the tangential friction of the air which brings the whole mass of the drops into relative motion, which can only take place gradually owing to the relatively greater viscosity of the water. Fig. 2 shows the motion as I have conceived it. Such a movement must, in the first instance, cause a flattening of the drop in its centrifugal box, and if the intensity is sufficient it will open itself into a horizontal ring,[2] which then by the force of surface tension soon changes into a ring of smaller drops. A corresponding phenomenon on the disappearance of drops is noted below (12).

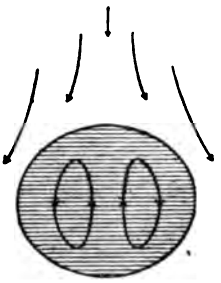


FIG. 2.

9. With reference to the motion of fall of medium and large drops we must say, from what has gone before, that the air resistance B, with the given value of the constant γ, represents very well the fall of such drops from a position of rest down to 3 m. [0·118 in.], but that its application is to be confined to raindrops for the very small interval of magnitude of drops which are too large for the case A but yet too small for their surface tension to protect them permanently from serious deformation by internal rotation—an interval which passes in the collective Table II. from 0·3–0·5 mm. diameter [·012–·020 in.]. All the velocities applying to greater diameters (C) in this table refer to the direct observations (Table I.), and have been obtained by direct interpolation from them. The curve employed for this gives for the size of drops of 4·5 mm. [·177 in.] a sharp curve to the horizontal direction. At the magnitude of about 0·5 mm. [·020 in.] it approaches a curve corresponding to the case B.

The Collision of Raindrops and Cloud Droplets.

10. Actual raindrops, under which designation we are always to understand

[1] *Wied. Ann.*, *l.c.* p. 230, 1887.

[2] Compare the observations on drops which have fallen into liquids; J. J. Thomson, *Proc. Roy. Soc. London*, 39, p. 416, 1885. It is to be remarked that in this case, as it appears (p. 418), the origin of the first flattening is to be attributed more to the pressure directed normally, which does not hold for drops in air, as explained above.

those of about 0·5 mm. [·020 in.] diameter and upwards,[1] according to Table II., do not fall with very variable velocity, the largest fall not much more than twice as fast as the smallest. Collisions among such drops must therefore be relatively very rare.[2]

TABLE II.—FINAL VELOCITIES OF WATER-DROPS FALLING IN AIR.

	Diameter of Drop $2r$. mm.	in.	Velocity v. m. per sec.	miles per hr.		Diameter of Drop $2r$. mm.	in.	Velocity v. m. per sec.	miles per hr.
A	0·01	·0004	0·0032	·007	C	1·0	·039	4.4	9·84
A	0·02	·0008	0·013	·029	C	1·5	·059	5·7	12·64
A	0·03	·0012	0·029	·064	C	2·0	·079	5·9	13·19
A	0·05	·0020	0·080	·17	C	2·5	·098	6·4	14·31
A	0·1	·0039	0·32	·71	C	3·0	·118	6.9	15·43
A	0·2	·0079	1·3	2·90	C	3·5	·138	7·4	16·55
					C	4·0	·157	7·7	17·22
B	0·3	·012	2·7	6·04	C	4.5	·177	8·0	17·90
B	0·4	·016	3·2	7·16	C	5·0	·200	8·0	17·90
B	0·5	·020	3·5	7·89	C	5·5	·216	8·0	17·90

It must therefore be common for these collisions to take place between these drops and the large number present in clouds, and which appear to be relatively at rest there; and this explains why the raindrops in falling reach the size with which they reach the ground.[3] For the difference of velocity with these collisions is considerable, and may cause the drops to unite. An experiment showed that a wire of 1·5 mm. [·059 in.] thick and completely wet, exposed to a rapid current of air at 10 m. per second [22 miles per hour] which was charged with small spray drops, took up a quantity of water which corresponds to about 50 per cent of the drops arriving at its section.[4]

The size of a raindrop cannot therefore be an absolute comparison with other drops falling at the same time, but must be a relative measure of their delay in the cloud.[5]

11. The collision of the small drops with each other must be very common, and it is these collisions which cause the drops to unite and to increase in size, and also cause the cloud to produce rain. Drops of 0·01 mm. [·0004 in.]

[1] This corresponds to the general expression as to the fact that the smaller droplets are mostly prevented from falling by the rising of the air.

[2] We find also that the mean distance between these drops is very small, even in the heaviest rains. It is represented by the third root of the motions of the mean velocity—6 m. per second [13·42] divided by the number of drops falling on 1 square metre in 1 second, which, *e.g.* in the case of a heavy fall, given below (Table III. column 9), is

$$\sqrt[3]{6:2300}=13\cdot8 \text{ cm.}$$

If the mean size of drops is 2 mm. [·079 in.], with such a distance a drop must pass over 210 m. [688 ft.] before its neighbours in order to collide with another.

[3] O. Reynolds (*l.c.*).

[4] We must not assume that all the drops driving towards the section come into collision, for the force of friction acts against the sluggishness of the drops and causes them to follow the current lines of the air around the obstacle. Accordingly, as many more drops must escape collision, the smaller they are the greater the obstacle of the drops which are collecting, and the smaller the relative velocity of the latter as regards the air. If, instead of the drops of spray, we had exposed the wire to the much finer cloud of steam from boiling water in a similar current, the wire would have taken up hardly any water (unless it was colder than the current). Wider bodies take up very little even in a current charged with spray. This corresponds to the fact that silver thaw only settles on small objects like twigs and wires, and never settles on flat surfaces.

[5] The path that it has described in this time is immaterial, for in every moment it must possess the velocity corresponding to the air and the drops therein floating, and therefore, with a given constitution of cloud, take up a quantity of water corresponding only to its velocity and size, and so in the last line depending on the time alone. (For the other influence of the changes of velocity of air, see the note to 15.)

diameter are, *e.g.* Table II., to be considered as almost at rest as compared with those of 0·03 [·0011 in.] diameter; and that such differences of size in clouds are the rule is shown by the comparative rarity of well-formed coloured lunar halos. If we take the mean diameter of the water-drops at 0·02 mm.[1] [·0008 in.] and their mean mutual distance at 1 mm.[2] [·039 in.], the change of place which a drop must make relative to its environment in order to strike another is $1 \text{ mm.}^2 : \pi \ (0{\cdot}02 \text{ mm.})^1 = 0{\cdot}8$ mm. [·031 in.]. If, therefore, there are drops of from 0·01 to 0·03 mm. diameter, this lateral movement, and so the collision, on the principles of Table II., following the movement of the mean drop, must take place every 50–80 seconds.

That in spite of these frequent collisions every cloud does not rain, agrees with the fact that liquid masses brought into contact do not easily flow together.[3] The reason of this is, that the sheet of air which covers each of the liquids and prevents their uniting requires time for its escape.[4] If, therefore, rain is to fall from a cloud, there must be some force, however small, which prevents the drops which have united from separating again before the sheet of air has disappeared. If there is such a force, the rain is set free.

As raindrops are always found to be electrical,[5] it is probable that electrical charges of the drops furnish this force. A drop charged with 0·000005 electrostatical units, and of 0·02 mm. [·0007 in.] diameter, can hold a second similar unelectrical drop at a distance of 0·001 mm. [·00004 in.] between the two surfaces,[6] so that it cannot be carried farther through the air, whose frictional force in falling depends on the amount of the weight. This is a charge only one hundredth of what may be attributed to every ordinary raindrop.[7] It is to be remarked that a reasonably dense piling together of drops of the given charge, these being always considered of the same character, would have the qualities of a powerful thunderstorm.[8]

Disappearance of Drops.

12. The large drops which float in the air current of the ventilator (6) often present the phenomenon of a sudden breaking up into small drops, which are then driven upwards and escape from the side of the current. This breaking up is always preceded by some floating; if the floating drop can escape easily enough from the air current, it does not break up even when its diameter is 6·4 mm. [·252 in.]. On the other hand, drops of 4·5 mm. [·177 in.] sometimes did not break up after floating for four or five seconds. If a largish drop has floated very quietly for some seconds, which is certainly not a common occurrence, we may observe the characteristic phenomenon, usually after a slight upward movement of the drop, that it suddenly changes itself into a

[1] Assmann found on the Brocken 0·006–0·017 mm. (·00024–·00067 in.) (*Met. Zeits.* **2**, p. 41, 1885); from lunar coronæ for 1° half measure of the first red ring 0·04 mm. [·0015 in.], for 2° 0·02 mm. [·0007 in.], according to the theory of the phenomenon developed by Verdet (*Ann. de Chem. et Phys.* **34**, p. 129, 1852).

[2] Corresponding to a cooling of saturated air from 20° to 6° C., and a mean diameter of the drop of 0·02 mm. [·0007 in.].

[3] Lord Rayleigh, *Proc. Roy. Soc.* vol. **28**, p. 406, 1879.

[4] E. Kaiser, *Wied. Ann.* vol. **53**, p. 667, 1894. There it is shown that the electrical forces producing the union (of the drops) can without doubt be referred to the usual mechanical forces of the electrical charges of the two liquids.

[5] Elster and Geitel, *Terr. Mag. u. Atm. Elect.*, March 1899, and the earlier publications there cited.

[6] Observed by E. Kaiser (*l.c.* p. 676) with two soap-bubbles brought just before in contact at a very slight pressure.

[7] Corresponding to 30 volts in five minutes on Elster and Geitel's apparatus, and 2000 raindrops per second and square metre (see Table III.).

[8] We may notice this, that the rapid re-formation of water-drops with electrical charges which do not fall short of these which take place in themselves, probably occur in every ordinary raining cloud.

pretty circular ring of small drops of equal size and equal distances from each other. There may be seven or nine drops in the ring. After unsteady floating, the disappearance was only irregular, which was the usual case.

The sudden entrance of the already deformed drops into a rapid air current is very favourable to their disappearance. If the conical cover of the apparatus (Fig. 1) were inverted so that the pointed end was at the bottom, a current escaped from it, and in this the velocity decreased as rapidly as it rose. Drops which came into this current did not easily escape from it, so that the opportunity was favourable for testing them as to their permanence. It appears that drops of the diameter of 5·4 mm. [·213 in.] exploded at once. The phenomenon of the ring formation did not come out. The number and size of the fragment were different in different cases. Of 36 drops only 4 (11 per cent) went into 2 nearly equal drops (passing into 3 nearly equal drops occurred, but not regularly), 9 (25 per cent) went into quite fine dust, the residue 23 (64 per cent) gave each one large drop with a number of small ones, of which the number was 1 with nine drops, 2 with nine also, 4 with two, 5 with one, and above 5 with two. Of the fragments which escaped laterally, all sizes,[1] from 1·5–3·5 mm. [·059–·138 in.] diameter were represented; greater fragments were rarer, but none exceeded 4·3 mm. [·169 in.].[2] The greatest number by far were the smallest, of 1 mm. [·039 in.] and below it, which were carried up to the ceiling by the current.

The relations of the experiments which were last employed were nearer to those in free air in strong motion than to those in quiet floating, for the velocity of the wind at considerable elevation is exposed to constant irregular changes.[3] In order to see if, when the pressure is suddenly and greatly altered, smaller drops could break up, I allowed such of 2·2 and 4·0 mm. [·087 in. and ·158 in.] to drop for 60 cm. [23·6 in.] through calm air into a current of 6 cm. width [2·4 in.] and 10 m. per sec. [22·37 miles per hour] velocity moving upwards rather obliquely but nearly vertically. The drops did not pass through the current, but were caught by it and carried laterally and upwards. When caught on blotting-paper they were always unbroken. We may therefore say that, in general, drops up to 4 mm. [·158 in.] diameter can find their way through the air unchanged, but that, on the contrary, those of 5 mm. [·197 in.] and above can only last for the time of a few seconds.[4]

13. In fact, I have not found a greater diameter than 5·2 mm. [·204 in.] with drops in a great number of showers, some of them very heavy. Herr Wiesner found (*l.c.* p. 1424 ff.) 4·9–5·3 mm. [·193–·208 in.] (0·06–0·08 grm.) [9–12 gr.] as not uncommon as the largest drops (and weight) in tropical rains;

[1] To be understood as below with rain (14).

[2] Herr Wiesner reports (*l.c.* p. 1423) on the following experiments carried out by him: "If you allow the water-drops falling from the sand filter "(dropping from a very wide surface) "to fall to a depth of 22–5 m., they burst asunder, a heavy drop falls first, then immediately after a smaller one, and the first, according to the absorption method" (catching on blotting-paper) "has a weight which is always under 2 gm." (7·2 mm. diam.). I was not able to make out from the accompanying text in how far, by the conclusion that we had to do with the bursting of a single large drop in its passage through the air, he had regarded the fact that when drops fall from so large a surface several form at once, viz. a first large drop, and immediately after it a smaller, or a group of these (see the photographic representations, *Wied. Ann.* vol. **30**, 1887). The weight of the following group increases with the width of the surface from which the drops fall, more rapidly than the weight of the chief drops, and so must have been especially large in the Wiesner experiments.

[3] Compare, for instance, S. P. Langley, *Smithsonian Contrib.* vol. **27** (No. 884), 1893.—On unsteadiness of vertical currents, see (15).

[4] Our results have no reference to drops holding much air, which appear to occur occasionally. Such drops have less specific gravity and greater internal friction than those of pure water, and those two circumstances show that they may be larger without breaking up. With these may be compared the large, whitish, slowly falling drops which have been observed by Herr Krümmel, *Met. Zeits.* **1**, p. 283, 1884.

6·2 mm. [·244 in.] (0·125 grm.) [0·185 gr.] with a downpour in August in Upper Austria; 6·7 mm. [·264 in.] (0·16 grm.) [0·64 gr.] was rare even in the tropics, and 7·3 mm. [·287 in.] (0·2 grm.) [3·08 gr.] never occurred. With rain of the latter character, with drops of the size of 5·5 mm. [·216 in.] and more, according to the above, a constant change must be going on in the drops in the air, to such an extent that every drop which has reached 5·5 mm. [·216 in.] breaks up before it has lasted 3 more seconds, or before it has fallen 24 m. [78 ft.] through air at rest. The larger fragments, in this fall must again increase by uniting with smaller drops, and then break up again, and so on. If this process results in producing a considerable increase of these unsteady large drops in the receiver, it must occur pretty often in the air; that is, the distance of fall (or the time) in which the greater fragments (4 mm.) [·158 in.] increase to 5·5 mm. [·216 in.] should not be great in comparison with the 24 m. [78 ft.] (or 3 seconds). This assumes a quantity of water in the air[1] which can only rarely occur, as shown by the rarity of the large drops.

Rain Observations.

14. The whole subject of the quantitative distribution of the size of rain-drops seems scarcely to have been studied, but a number of characteristic examples will be found in Table III., which follows. The determination was effected by catching the drops on blotting-paper (see 6) which was exposed in a free place: it was in a shallow wooden box, with a shutter which was rapidly opened and shut again, and was kept horizontal. The size of the paper was 100 or 200 square cms., the duration of exposure from 1 to 120 seconds according to the heaviness of the rain. In order to facilitate comparison, all the drop rain has in the table been referred to 1 square metre and 1 second. The pictures of the drops, after being completely absorbed, were at once fixed, and for this purpose the paper was sprinkled with the dust of a dye-stuff soluble in water (*e.g.* eosin) and the superfluous dust shaken off. In this way we obtained exact and authentic representations of the drops which fell on the paper, which could be remeasured at any future time, and thereby affords a thorough means of measuring drops. The paper was tested by carefully weighed drops, and was so thick that drops of $\frac{1}{4}$ mm. as the smallest came out quite visibly. In the table the drops are grouped into sizes and classes, so that all drops under $\frac{3}{4}$ mm. diameter came into the class 0·5 mm., all between $\frac{3}{4}$ and $\frac{5}{4}$ mm. to the class 1 mm., and so on in further steps of $\frac{1}{2}$ mm. difference and diameter—a numbering which does not take much time, if you have small circles to compare with each of the degrees of size. If there are large drops in the fall, they cover themselves over a considerable number of smaller drops. A correction must be introduced for this, in the following way: you allow for the number of small drops on the large drops the same number of small drops as appear on an equal area of the paper showing no large drops. The figures of the large drops are not materially affected by the small drops. If two drops of similar size overlap one another, this can be seen by the circumstance that the edge of the drop is not circular. With heavy rains, where these complications occur, the combination is shorter, and a longer time of exposure is desirable.

Among the drop numbers of the individual classes, you find in the table as the sum of these numbers the total number of drops per square metre and second. The last column in some cases gives the depth of rain calculated from the drop numbers and the volume given in column 3. This depth of rain is much affected by the biggest drops, the smaller ones giving only a slight contribution to it, if they occur in large numbers, as in the cases 1 and 2. Also the

[1] By the assumption of 100 m. for the depth of fall, of the increase of more than 30 grms. water in the form of small drops in one cubic metre of air.

appearance and the noise with such falls is greater the more abundant the large drops are. The fall 10*b* appeared, *e.g.*, although it had fewer drops, slack as compared with 10*a*, owing to the fall of 101 large drops.

TABLE III.

Drops. Diameter. in.	mm.	No. sq. mm.	No. of Drops per Square Metre and Second. Fall No. 1	2	3	4	5	6	7*a*	7*b*	8	9	10*a*	10*b*	10*c*
·019	0·5	0·066	1000	1600	600	14	129	60	160	140	0	100	514	679	7
·039	1·0	0·523	200	120	240	9	100	280	160	580	50	1300	423	524	233
·059	1·5	1·77	140	60	20	10	73	160	80	280	50	500	359	347	113
·079	2·0	4·19	140	200	20	0	100	20	0	100	150	200	138	295	46
·098	2·5	8·19	0	0	0	0	29	20	0	40	0	0	156	205	7
·118	3·0	14·2	0	0	0	0	57	0	0	0	200	0	138	81	0
·138	3·5	22·5	0	0	0	0	0	0	0	0	0	0	0	28	32
·157	4·0	33·5	0	0	0	0	0	0	0	20	50	0	0	20	39
·177	4·5	47·8	0	0	0	0	0	0	0	0	0	200	101	0	0
·196	5·0	65·5	0	0	0	0	0	0	0	0	0	0	0	0	25
Total number			1480	1980	880	33	486	540	400	1160	500	2300	1840	2190	500
Raindrops $\frac{\text{mm.}}{\text{min.}}$			0·09	0·06	...	...	...	...	...	...	0·32	0·72	0·57	0·34	0·26

Fall No. 1. 1898, September 28, 12.55 p.m.—On the slope of Pilatus (near Lucerne), at about 1400 m. [4600 ft.] above sea-level. Rain looking very ordinary ; light wind. According to the weather reports of Swiss Met. Zentral. Inst., rain at same time over all North Switzerland.

" 2. Continuation of same fall, 5.10 p.m.—Pilatus top enveloped in cloud ; a strong gusty wind had set in a little before. Up to that time the rain had the same size of drops as in No. 1, and also on the top of Pilatus.

" 3. 1898, October 2, 12.2 a.m. Lugano.—A fall which had begun at 6 p.m. on previous day with large drops, looking very ordinary ; very little wind. Electricity of air and rain often changing in sign but not attaining any abnormal intensity.

" 4. 1899. June 24, 8.45 p.m. Kiel.—Very slight rain lasting a short time, almost calm, and the sky uniformly covered in grey ; this had formed itself during the day.

" 5. 1899, June 25, 10 a.m. Kiel.—Rain, with sunshine breaks ; some wind.

" 6. 1899, May 24, forenoon. Kiel.—Beginning of a short fall like thundershower ; distant thunder.

" 7*a*. 1899, May 24, afternoon. Kiel.—Stormy cloud formation, with sunshine breaks ; first drops.

" 7*b*. 1899, May 24, afternoon. Kiel.—Rain, heaviest period.

" 8. 1899, July 9, 4 p.m. Kiel.—Sudden rain from a small cloud coming up on south horizon. Zenith blue, with gleams of sun. Calm ; sultry before.

" 9. 1899, September 10, 5.30 p.m. Kiel.—Violent rain like a cloudburst, with some hail.

" 10*a*	1899	*a*. Heaviest period		of one and the same continuous fall, and at times took the form of a cloudburst, and so allowed of the three great divisions of drop size reappearing almost mechanically again and again.
" 10*b*	July 3	*b*. Less heavy period		
" 10*c*	9–10.30 a.m.	*c*. Period of stopping		

This fall, which began on July 1 late at night with a cloudburst and lasted through 2nd and 3rd with pauses, gave a large proportion of the average yearly rainfall of Kiel. It was preceded on July 31 [? June 30] by a stream of cirrus and solar halo.

Influence of Ascending Currents on the Size of Drops.

15. The ascent of the air is a necessary condition for the production of the store of water in every fall, but very slight air velocities suffice for the production of almost all falls. For example, a saturated current of air at 20° C. [68° F.] and moving at the rate of 1·2 m. per sec. [2·68 miles per hour], if it were cooled to 6° [42°·8 F.], could yield the fall of ·72 mm. [·028 in.] which was obtained in the cloudburst 10*a*. Such a current, according to Table II., could only prevent the smallest drops, under 0·2 mm. [·008 in.] diameter, from falling.[1] It may therefore be assumed not to be present in ordinary raindrops.

Strong ascending currents, on the other hand, have a considerable influence on the character of the mixture of drops that reach the earth. A velocity of 8 m. per sec. would stop all fall of rain, and velocities higher than that could, as long and as far as they extend, lift any quantity of water to any height. A constant velocity of 7 m. per sec., according to Table II., would only allow the sizes 3·5 mm. [·138 in.] and above that to fall, but would keep up the smaller ones; and for 6, 5, 4 m. per sec., the lowest class that falls would be 2·5, or possibly 1·5 or 1·0 mm. It is not till the velocity is 3 m. per sec. [6·71 miles per hour] that all the magnitudes of Table III. first appear on the collecting plate. Falls whose composition corresponds in this way to velocities of 7, 6, and 5 m. per sec. have never been obtained by me. But yet ascending currents of this velocity cannot be uncommon: they often occur horizontally. They, however, have not the continuity requisite to separate the different sizes,[2] as the horizontal currents are never continuous.

We therefore take the ascending air velocity as, within certain limits, variable in extent and time.[3]

Tumultuary Rain.

16. If the upper limit of the ascending current is not far below 8 m. per sec., or above it, the current can at times and in places carry considerable quantities of water upwards, so that the drops have time to grow and so that the process of disappearing and forming again which has been described (13) can come into play.

It appears, therefore, that at times and in places of less velocity an excessive number of drops of the largest classes, or, if it is freezing above, hailstones, may come about, while the drops which fall direct from the cloud must be much smaller. In this way we must explain the very remarkable gaps in the size of the drops in the falls Nos. 7*b*, 9, 10*a*—that of No. 9 was really mixed with hail, and all of them gave the idea of falling by fits and starts.

[1] You would therefore rarely find such drops in heavy rains.

[2] The simple reference of raindrops to the magnitude of the vertical component of air velocity (according to the description in meteorological text-books, see note 2, p. 63), from Ferrel's representation of rain, is inadmissible. It seems more likely to be right to hold to the view (10) that the size of each raindrop under the diameter of 4·5 mm. [·177 in.] (12) is a relative measure for the time which has elapsed since its origin and its final escape from the raining cloud. The explanations given above are based on that.

[3] Variations of wind velocity will have an influence in increasing the size of the drops, as they must throw smaller drops against the larger, and this has also to do with the variations of the horizontal components of the wind velocity. However, this influence can only occur with variations of great suddenness, force, and frequency. A full, sudden change of wind velocity of 10 m. per sec. would, *e.g.* according to B, in 54 seconds carry over two-thirds of all drops of 1 mm. diameter, and so be of material importance for the growth in that short time.

It may also be attributed to the ascending component of these falls that the smallest drops, 0·5 mm., were remarkably rare. The complete disappearance of this class would correspond to a wind velocity not falling below 4 m. per sec. This occurs with the falls of Nos. 8 and 10*c* entirely, and in other cases is very nearly realised ; but these are not phenomena of long continuance. Fall No. 8 fell in calm from a cloud suspended near the blue zenith ; it reminded us strongly of an experiment with the ventilator (6), where heavy floating drops passed laterally out of the current, to fall quietly to the ground in the calm air close by. Rain No. 10*c* was a cloudburst just coming to an end, and its subsequent course is shown in 10*a* and 10*b*. From the rarity of the smallest drops it is not to be doubted that it had not to do with a stoppage in the rain production, but with a temporary increase in the ascending current over the place of observation.

If we summarise the character of the drop mixture which strong, discontinuous, ascending currents let us expect, and which appear in Nos. 7*b*, 8, 9, 10*a*, and 10*c* in Table III., we may describe it as consisting in the failure or much-reduced frequency of the smallest class of drops, and in the presence of great drops which last longer, but by the failure of intermediary steps. For the falls of this character I have proposed the term "tumultuary."[1]

Still Rain.

17. An ascending current with velocities between 2 and 0 m. per second suffices to produce ordinary rain, but allows the movement and growth of the actual drops to go on quietly as in air at rest, even if its velocity is variable within these limits ; we therefore get this name for such falls.

To this belong most of the usual land rains, of which Nos. 1 and 3 of Table III. are examples. The size of each drop that comes down can in this case be set as proportional to the thickness of the sheet of cloud it has passed through.[2] If, therefore, a homogeneous cloud rained equally from all its volume, it must give an equal number of drops of each size, from the smallest to the largest. This, however, appears rarely to occur (see Table III.). It is usual to find more small than large drops, which shows that most of the drops are found in the lower parts of the cloud.

Changes from quiet to tumultuary rain must occur when the ascending current reaches 2 m. per sec. [4·47 miles per hour] but does not come near 8 m. per sec. [17·90 miles per hour]. Examples of this may be seen in No. 2, Table III., after the freshening of the wind in No. 1, and also in 5 and 6.

Measurement of Well Levels.

The Underground Water Preservation Association has issued a chart for the weekly registration of the level of water in wells and streams, and also of the rainfall.

The following particulars may be helpful to any one who has an opportunity of making such observations.

In measuring wells, a definite level should be selected at the top of the well to measure from, such as a sill or floor level, which level should be invariably adhered to.

The following should be ascertained and recorded on the chart when well measurements are commenced :—(1) Ordnance Datum (O.D.) level of sill (if

[1] Compare the names used for discontinuous liquid movements of certain kinds. C. V. Bjerknes, *Hydrodynamische der Fernkräfte*, vol. 2, p. 132, 1902.

[2] If the cloud consisted of drops of 0·02 mm. [·0008 in.] diameter at a mean distance *inter se* of 1 mm. [·039 in.] (see 11), and if 50 per cent of them were caught (see 10), the diameters of the drops of 1, 2, 3, 4 sheets of clouds correspond to a force of 0·5, 1, 1·5, 2 km.

possible); and (2) depth of well (sill to bottom), which is determined by lowering a weight at the end of a tape or cord and measuring length of same.

The record is made by noting the length of the wetted cord, or by lowering line or Chesterman tape with attached flat lead (3 ins. diam. $\times \frac{1}{2}$ in. thick) to the surface of the water. In the former case the depth of water is got at by direct measurement, and in the latter by deducting the distance measured from total depth of well.

The Association urges very strongly the necessity for such systematic records, which are of value not only to the Association but also to the observer.

If records are taken weekly or fortnightly, the same day in the week and, as near as possible, the same time of day should be adhered to. In cases of any unexpected depth being recorded it is as well to measure again for a few days in succession to test the accuracy of the observation.

In a well from which a large amount of water is pumped, the levels are often materially depressed by the artificial abstraction of water. In such cases the "rest" level should be taken (*i.e.* the permanent level when the pumps are stopped). This is best done in most cases early on Monday morning, before the pumps are started up. The level whilst pumping is going on, say on Saturday before shutting down, might with advantage also be taken and recorded.

Scotia Bay Meteorological and Magnetical Station.

Mr. William S. Bruce has received information from Mr. Walter G. Davis of the Officina Meteorologica Argentina, that already arrangements are made to send the *Uruguay* to relieve Mr. Robert C. Mossman, F.R.S.E., at present in charge of the Argentine Meteorological and Magnetical Station in the South Orkneys. This important station was set up by the leader of the Scottish National Antarctic Expedition, and that expedition made complete records there for a whole year. Thereafter Mr. Bruce handed the station and equipment over to the Argentine Government, who asked Mr. Mossman, Meteorologist and Magnetist to the Scottish Expedition, to remain in charge. Three Argentine scientists—Messrs. Szmula, Valette, Acunha—and the second steward of the *Scotia*, William Smith, formed Mr. Mossman's staff. The *Scotia* left the South Orkneys on February 22, after Mr. Bruce had landed coal and other necessaries, and had constructed a large storehouse for the coal and provisions. It is proposed to send out the relief ship in October—a time which appears to be rather early, from the experience of the Scottish Expedition, who found heavy ice round the South Orkneys up to the end of November in the more favourable year, namely 1903-1904, and for the whole summer in 1902-1903. December would appear to be a more favourable season for sending this relief ship, particularly as she is not specially adapted for ice navigation.

The Government of the Argentine Republic intend, besides relieving Mr. Mossman's party, to continue and extend the work of the station. A complete set of instruments from Toepfer and Son of Potsdam, both for the determination of the constants and for the self-recording of the variometers, have been procured, and are being sent out with the relief ship.

Mr. Davis is delighted that Mr. Mossman consented to remain in charge of the station a second year, as he says by so doing it has ensured the Argentine Meteorological Office of the best possible results from the observations initiated by the Scottish Expedition and carried on by them.

There is some difficulty, however, in finding a man capable of taking charge in succession to Mr. Mossman, and although Mr. Bruce has been assisting Mr. Davis in the search for a trained magnetist, yet up till now he has been unsuccessful in finding that *rara avis.*—*Scottish Geographical Magazine*, October 1904. (See also pages 14 and 38.)

A Kite struck by Lightning at Hamburg.

At the Kite Station of the Seewarte, in Gross Vorstel, Viola Strasse, on July 1, at 11.11 a.m., a kite was sent up with three kites attached, and of these the first kite with the instrument reached a height of 5970 feet. As the pull was very slight (37 lbs.), we wished to attach another kite, when suddenly we saw a thunder-cloud come up, a dark cumulo-nimbus, so that we gave up the idea of the fourth kite until the squall should have passed over.

The Assistant at the Institute, Dr. Perlewitz, and I [Dr. Assmann], had just made an arrangement for breaking connection with the main wire, when suddenly the flash came. It was an interesting moment: first there was a sharp shock, then a stream of flame with a shower of sparks, accompanied by an explosion like cannon, and two seconds after came the thunder. Then we saw a stream of smoke as thick as a man's arm, for the lightning had burnt up the whole main wire up to the kite and instrument, although the latter had been quite 2000 feet above the cloud, for a total length of nearly two miles. We found afterwards molten drops of metal of peculiar form. Several splices which were on the wire at various levels, and served for the attachment of the additional kite, were uninjured, even as far as the doubling.—*Das Wetter*, July 1904.

Observations at Lassa, Tibet.

Climatic data from the forbidden city of Tibet have been obtained by M. Tysbikov, a Russian traveller, who resided in Lassa from August 15, 1900, until August 22, 1901. The following summary of his observations is taken from *La Géographie*, vol. 9, No. 1:—

The year is divided into two seasons, the dry and the wet. (The influence of the monsoons of the Indian Ocean is felt even at this point.) In 1900 the dry season began towards the end of September; up to the end of April snow fell only twice. The rains began toward the middle of May, and 48 rainy days were counted up to the middle of September. The direction of the winds is in general from West to East.

The mean temperature in the shade, observed three times a day during 235 consecutive days, is 41°·4 at dawn, 58°·1 at 1 p.m., and 48°·3 at 9 p.m. The coldest month is December (mean for the three observations respectively 18°·3, 36°·5, 26°·8); the warmest month is June (58°·3, 75°·0, 63°·0). The large streams never freeze; the small ones are covered with only a thin layer of ice.—*Monthly Weather Review*, September 1904.

RECENT PUBLICATIONS.

Bericht über die Ergebnisse der Beobachtungen für das Liv-Estländische Regenstationennetz, 15*-jährige Mittelwerte der Niederschlagsmenge, Anzahl der Niederschlagstage und Temperatur für den Zeitraum* 1886-1900 *zusammengestellt.* Von Prof. Dr. B. SRESNEWSKY und herausgegeben von der Kaiserlichen, Livländischen Gemeinnützigen u. Okonomischen Sozietät, Jurjew, 1904. 8vo. 47 pp. and 2 maps.

Herr Sresnewsky, already well known for his contributions to the *Repertorium*, has given us 15 years' means of the rainfall at the stations of the Agricultural and Economical Society of Livonia. The paper is illustrated by Monthly Charts.

Die Sommernachtfröste in Schweden, 1871-1900. Von H. E. HAMBERG. Stockholm, 1904. 4to. 94 pp. and 4 pl.

Dr. Hamberg has frequently written papers on these frosts, so destructive to crops. The present paper is very elaborate, as it deals with the different crops

affected and the different districts. It does not admit of being extracted, and we do not notice any allusion to the subject of possible foretelling of these frosts, a matter often mooted in past years.

Die Temperaturverhältnisse von Ungarn. Von S. RÓNA und L. FRAUNHOFFER. Publikationen der Königl. ung. Reichsanstalt für Meteorologie und Erdmagnetismus, 1904, Band 6. Budapest, 1904. 4to. 155 pp. and 5 pl.

This is a well-drawn-up paper, copiously illustrated, on the temperature of Hungary, and it well deserves careful study.

Indian Meteorological Memoirs. Published under the direction of G. T. WALKER, M.A., F.R.S., Meteorological Reporter to the Government of India. 15. Part 3.

This part contains a discussion of monthly mean surface and underground temperatures deduced from observations taken at Lahore, Jaipur, Dehra Dun, Allahabad, and Calcutta, during the years 1880-1901, by R. L. Jones.

Klimatographie von Österreich. Herausgegeben von der direktion der K. K. Zentralanstalt für Meteorologie und Geodynamik. 1. *Klimatographie von Niederösterreich,* von J. HANN. Wien, 1904. 8vo. 2 + 104 pp. and map.

Dr. Pernter announces that this is the first part of a general climatology of Austria, which was promised as forthcoming by the Minister for Culture and Education at the Jubilee Festival of the Central Institute in 1901.

As may be expected, everything is most thoroughly treated. The main districts are three: the forest region, the region about the Manhartsberg (north-west of Vienna), and lastly the region of the Wienerwald and the Southern Danube region with the outlines of the Alps. It is illustrated by a shaded rain map.

Report of the International Meteorological Committee, Southport, 1903. Published by the Authority of the Meteorological Council. London, 1904. Official No. 164. 8vo. 106 pp.

The International Meteorological Committee met at Southport during the session of the British Association, September 9-15, 1903. Monsieur E. Mascart of Paris was President, and Dr. H. H. Hildebrandsson of Upsala, Secretary.

This volume contains, in addition to the Minutes of Proceedings, reports on the following subjects:—"Proceedings of the International Committee for Scientific Aeronautics," by H. Hergesell.—"Aerial Soundings carried out at the Observatory for Dynamical Meteorology at Trappes," by Teisserenc de Bort.—"Meteorological Observations obtained by the use of Kites off the West Coast of Scotland, 1902," by W. N. Shaw and W. H. Dines.—"Progress in exploring the Air at Blue Hill Observatory; and a Project for making Atmospheric Soundings above the Equatorial Oceans," by A. L. Rotch.—"The Work of the Aeronautical Observatory of the Royal Meteorological Institute of Berlin," by R. Assmann.—"Simultaneous Solar and Terrestrial Changes," by Sir Norman Lockyer.—"The Use of Radio-active Substances as Collectors of Atmospheric Electricity," by Adam Paulsen.—"The Application of Radium Salts to the Study of Atmospheric Electricity," by M. Moureaux.—"The Meteorological Service of the Azores," by F. A. Chaves.—"The Use of the Hair Hygrometer instead of the Psychrometer," by J. M. Pernter.—"Note on the Hair Hygrometer,"

by Gen. Rykatchew.—"Report on Radiation," by J. Violle.—"Resolutions relating to Atmospheric Electricity adopted by the Associated Academies of Göttingen, Leipzig, Munich, and Vienna," and "A Projected Regular Night Service at the Nicholas Central Physical Observatory for Forecasting the Weather," by Gen. Rykatchew.

Report of the Meteorological Council, for the year ending 31*st March* 1904, *to the President and Council of the Royal Society.* Presented to both Houses of Parliament by Command of His Majesty. London, 1904. 8vo. 203 pp. and 2 pl.

The first part of this Report deals with the meeting of the International Meteorological Committee during the session of the British Association at Southport in September 1903. An Exhibition of objects of interest in Meteorology, terrestrial magnetism, and allied subjects was arranged in connection therewith, and arrangements were also made for the local issue of Daily Weather Reports.

Particulars are given of the work carried on by the various branches of the Meteorological Office, which are:—1. Marine; 2. Forecast and Storm Warning; 3. Statistics; 4. Observatory; 5. Correspondence.

It is proposed to discontinue the publication of the values from the Jordan Sunshine Recorder, as the Meteorological Council have decided that in future only the results obtained with the Campbell-Stokes or some other equivalent instrument shall be included in the official publications.

A new feature in this Report is the arrangement of the "Accessions to the Library" (Appendix X.) on the lines of the *International Catalogue of Scientific Literature*, and which occupies 49 pp. This arrangement, however, does not strictly adhere to that of the *International Catalogue*, so it has been necessary to elaborate some fresh rules in order to make the matter clear.

Report of the South African Association for the Advancement of Science. First Meeting, Cape Town, 1903. 8vo. 566 pp.

This volume is the Report of the First Annual Meeting of the South African Association, which was held at Cape Town, April 27 to May 2, 1903.

The following papers dealing with or bearing on meteorology are printed in this volume:—"Meteorology in South Africa—a retrospect and prospect," by Charles M. Stewart, B.Sc. (10 pp.). Mr. Stewart gives a historical sketch of the meteorological work in South Africa from the time that the first regular meteorological record was kept by the Abbé de la Caille in 1751, down to the present time, and also deals with the question of finances, and concludes the paper with a few general remarks and suggestions.—"Meteorological Records of the Transvaal," by W. Cullen (14 pp.). The paper is a summary of the meteorological observations taken at the station attached to the Dynamite Factory, Modderfontein, 1898-1902. The results are given in a series of diagrams.—"A preliminary note on some observations on atmospheric electricity in Cape Town and Bloemfontein," by Dr. J. C. Beattie, W. H. Logemann, and J. Lyle (4 pp.).—"The determination of mean results from meteorological observations made at second-order stations on the table-land of South Africa," by J. R. Sutton (25 pp.).—"The historical development of the geographical botany of Southern Africa," by R. Marloth (7 pp.).—"Some aspects of South African Forestry," by D. E. Hutchins (8 pp.).—"The irrigation question in South Africa," by W. Westhofen (10 pp.).—"The Artesian Wells of the Cape Colony," by B. W. Rilso (21 pp.).

The following extract from the Report of the Council will show that the science of meteorology is not being neglected by the Association:—"The Local

Committee of the Association at Johannesburg having moved in the direction of securing the establishment of a Meteorological Department in the Transvaal, the Council co-operated in pressing the matter on the attention of the Transvaal Government. The Government kindly consented to the petition, and it is anticipated that much useful work will be the result."

The Cyclones of the Far East. By Rev. José Algué, S.J., Director of the Philippine Weather Bureau, Manila Observatory. Second (Revised) Edition. Department of the Interior, Weather Bureau, Manila, 1904. 4to. 283 pp.

The first edition of this work appeared in 1897, in the Spanish language, under the title of *Baguios ó cyclones Filipinas.* Since that time much additional data have been obtained, and so this second edition is an enlarged and revised work. It is now issued in the English language in order to render the results accessible to as many seafaring men as possible.

The scope of the work will be best described by the following list of contents:—

The Science Year-Book, with Almanac, Diary, Biographical Directory, Summary of Progress in Science, List of Scientific Societies, and Glossary, for 1905. (First year of issue.) Edited by Major B. F. S. Baden-Powell. London [1905]. 8vo. 8 + 168 + 392 + 4 pp. and 2 pl.

During recent years *Knowledge Diary and Scientific Handbook* has been issued in conjunction with *Knowledge.* The latter periodical, however, having during

the past year changed hands and become amalgamated with the *Illustrated Scientific News*, the editors considered it desirable to bring out a rather different form of annual handbook.

The present volume is a great improvement upon its predecessors, and will be found a really useful aid to all interested in science.

The subjects are grouped under the following headings :—Astronomy ; The Earth and its Inhabitants ; Physical and Chemical ; Metrology ; Scientific and Technical Institutions ; Summary of Science Progress ; Biographical Directory ; and Diary. In addition to numerous meteorological tables, the work also contains articles on "Cosmical Physics," by Dr. W. J. S. Lockyer, and "Meteorology in 1904," by W. Marriott.

The Diary, which has a page for each day of the year, is of great interest and value to the Meteorologist, for in addition to the usual information as to the times of sunrise, sunset, planets, high water, etc., it has spaces for the entry of meteorological observations. There are also printed the "record" maximum and minimum temperatures since 1841, as well as the mean maximum and minimum temperatures for the day at the Royal Observatory, Greenwich. The following is a specimen of the readings on January 1 :—

Max. Temp.		Min. Temp.	
Highest	56°·5 ('51)	Highest	51°·7 ('83)
Lowest	26·0 ('87)	Lowest	18·2 ('75)
Mean	42·8	Mean	33·6

U.S. Department of Agriculture. Weather Bureau. Bulletin M. The Floods of the Spring of 1903, *in the Mississippi Watershed.* By H. C. FRANKENFIELD. Washington, 1904. 4to. 6 pp.

This is a report on the spring floods of 1903 in the Ohio, Mississippi, and lower Missouri valleys, and it is accompanied by numerous interesting photographs, maps, and charts. The floods of March and April in the Ohio and lower Mississippi rivers were especially noteworthy for the unprecedentedly high stages that occurred over the latter. From Memphis to the Passes, the stages of the water were greater than ever before known, except in a few localities. The excesses over the highest previous stages, principally those of 1897, ranged from 0·9 foot at New Orleans to 2·8 feet at Memphis. During the floods of May and June 1903, the stages of the water at some places exceeded any previous known records. The Weather Bureau issued forecasts and warnings which were very accurately fulfilled. The following figures show the stages forecasted and those actually reached at various places from Cairo to New Orleans; the forecast at the former place was made four days in advance, and that at the latter twenty-eight days in advance of the flood crest.

Stations.	Forecast Stage.	Actual Stage.	Stations.	Forecast Stage.	Actual Stage.
Cairo	50·5 to 51·0 ft.	50·6 ft.	Greenville	49·0 ft.	49·1 ft.
Memphis	40·0	40·1	Vicksburg	52·0	51·8
Helena	51·0	51·0	New Orleans	21·0	20·4 to 20·7
Arkansas City	53·0	53·0			

Weather Influences. An Empirical Study of Mental and Physiological Effects of Definite Meteorological Conditions. By EDWIN GRANT DEXTER, Ph.D. New York and London, 1904. 8vo. 31 + 286 pp.

The author collected statistics on the attendance, behaviour, and work of school children, and on the cases of crime, insanity, health, suicide, drunkenness, attention, etc., at Denver and New York, and compared these with the meteorological conditions. His conclusions are as follows :—

1. Varying meteorological conditions affect directly, though in different

ways, the metabolism of life. By "metabolism of life" the author means those processes of oxidation, either within the lungs or other tissues of the body, which are the chemical basis of life as we know it.

2. The "reserval energy" capable of being utilised for intellectual processes and activities other than those of the vital organs is affected most by meteorological changes.

3. The quality of the emotional state is plainly influenced by the weather states.

4. Although meteorological conditions affect the emotional states, which without doubt have weight in the determination of conduct in its broadest sense, it would seem that their effects upon that portion of the reserve energy which is available for action are of the greatest import.

5. Those meteorological conditions which are productive of misconduct in a broad sense of the word are also productive of health and mental alertness; as a corollary, misconduct is the result of an excess of reserval energy not directed to some useful purpose.

On the whole, it would seemingly be safe to say that of the activities (or cessation of activity) possible to human beings, some are the result of excessive vitality, and others of a deficiency; and that, generally speaking, those misdemeanours which have been classed under those of conduct are the results of the former, while sickness and death are accompaniments of the latter.

This work also contains an introduction by Professor Cleveland Abbe.

Zwölfter Jahres-bericht des Sonnblick-Vereines für das Jahr 1903. Wien, 1904. 4to. 41 pp. and 2 pl.

This contains the following papers—"Der Winter auf dem Sonnblick," by Otto Szlarck; "Die Bravaissche Erscheinung auf dem Sonnblick," by Otto Szlarck; "Auf Bergobservationen und Vorgänge in höheren Luftschichten bezügliche Publikationen im Jahre 1903," by A. von Obermayer. The results of the observations at heights of 2992 ft., 3360 ft., 3937 ft., and 10,190 ft. are also given.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of general interest.

For a full Bibliography the reader is referred to the *International Catalogue of Scientific Literature.*

A[bbe], C.—The Diurnal Variation of the Barometer at Milwaukee. *Monthly Weather Rev., Washington*, **32**, 1904 (376-377).

Abbot, H. L.—Hourly Climatic Records on the Isthmus of Panama. *Monthly Weather Rev., Washington*, **32**, 1904 (267-272).

Algué, J.—The first Electric Storm recorded automatically in St. Louis, Mo. *Monthly Weather Rev., Washington*, **32**, 1904 (273-274).

Andson, W.—The St. Swithin's Day Tradition. *Symons' Met. Mag., London*, **39**, 1904 (175).

Angot, A.—La pluie à Bouin (Vendée). *Ann. Soc. Mét. France, Paris*, **52**, 1904 (173-177).

Assmann, J.—Ein Gewitter regen von 84 Millimeter in 45 Minuten. *Wetter, Berlin*, **21**, 1904 (212-213).

Bacon, J. M.—On Upper Currents and their relation to the hearing of Far Sound. *Symons' Met. Mag., London,* **39**, 1904 (149-150).

Barbé, G.—La température en juillet, 1904. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (177-181).

Bebber, W. J. van.—Klimatafeln für die deutsche Küste. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (529-538).

Bergholz, P.—Ein Klimatologischer Atlas des indischen Reiches in Sicht., *Meteor. Zeits., Vienna,* **21**, 1904 (469-470).

Berthoud, P.—Meteorologia de Lourenço Marques. *Bol. Soc. de Geog., Lisbon,* **22**, 1904 (176-178, 210-212, 255-257, 294-296, 326-328, 358-360).

Besson, L.—Attempts at Methodical Forecasting of the Weather. Translated from *Ann. Soc. Mét. France,* **52**, 1904 (92-97), by Miss R. A. Edwards. *Monthly Weather Rev., Washington,* **32**, 1904 (311-313).

Bigelow, F. H.—Studies on the Circulation of the Atmospheres of the Sun and of the Earth. VII. The Average Monthly Vectors of the General Circulation in the United States. *Monthly Weather Rev., Washington,* **32**, 1904 (260-263).

Bock, J.—Untersuchungen über das Tönen der Telegraphen- und Telephonleitungen. *Wetter, Berlin,* **21**, 1904 (185-190).

David, P.—Inversions de temperature en altitude. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (216-218).

Die Eisverhältnisse an den deutschen Küsten im Winter 1903-04. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (401-407).

Die Ergebnisse der erdmagnetischen Beobachtungen in dem deutschen Küstengebiete und in den deutschen Schutzgebieten während des Jahres 1903. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (419-424).

Die Witterung zu Tsingtau im Juni, Juli und August 1904, nebst einer Zusammenstellung für den Sommer 1904. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (525-529).

Dines Recording Barometer. *Symons' Met. Mag. London,* **39**, 1904 (150-151).

Dines, W. H., and Shaw, W. N.—Investigation of the Upper Atmosphere by means of Kites in co-operation with a Committee of the Royal Meteorological Society. Third Report of the [British Assoc.] Committee. *Symons' Met. Mag., London,* **39**, 1904 (147-149).

Drapczyński, V.—Über die Luftströmung in der Umgebung der Barometer-Minima und -Maxima zu Moskau. *Meteor. Zeits., Vienna,* **21**, 1904 (376-377).

Duckworth, Sir D.—Remarks on British Winter Resorts. *J. of Balneology and Climatology, London,* **8**, 1904 (267-275).

Dufour, C.—Observations météorologiques de l'expédition antarctique de "*La Belgica.*" *Ann. Soc. Mét. France, Paris,* **52**, 1904 (181-184).

Durand-Gréville, E.—Précautions à prendre dans l'étude d'un grain orageux. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (213-215).

Ekholm, N.—Wetterkarten der Luftdruckschwankungen. *Meteor. Zeits., Vienna,* **21**, 1904 (345-357).

Eliot, Sir J.—Opening Address to Subsection of Cosmical Physics, Cambridge, 1904. [Indian and Imperial Meteorology.] *Nature, London,* **70**, 1904 (399-406); *Symons' Met. Mag., London,* **39**, 1904 (142-147 and 165-170); *Observatory, London,* **27**, 1904 (327-337).

Exner, F. M.—Einiges über das Wetterbureau der Vereinigten Staaten von Nordamerika. *Meteor. Zeits., Vienna,* **21**, 1904 (465-469).

Forster, A. E.—Die klimatischen Verhältnisse von Eger-Franzensbad und Marienbad in Böhmen. *Meteor. Zeits., Vienna,* **21**, 1904 (382-383).

Friesenhof, G.—Einiges über Ozonbeobachtung. *Meteor. Zeits., Vienna,* **21**, 1904 (380-382).

Götz, P.—Merkwürdige Erscheinungen am Abendhimmel. *Meteor. Zeits., Vienna,* **21**, 1904 (390-391).

Goutereau, C.—Sur l'affaiblissement du rayonnement solaire en 1902-1903. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (189-195).

Guzmán, J.—Climatologiá de la Republica Mexicana desde el punto de vista higiénico. *Mem. Soc. Cient. "Antonio Alzate," Mexico,* **20**, 1903 (181-288).

Hall, M.—The Origin of the Cuba Cyclones of June 13-14, 1904. *Monthly Weather Rev., Washington,* **32,** 1904 (366-368).

Hann, J.—Abweichungen der Jahres summen des Regenfalles zu Padua, Klagenfurt und Mailand zwischen 1725 und 1900. *Meteor. Zeits., Vienna,* **21,** 1904 (424).

Hanzlik, S.—The Annual and Geographical Distribution of Cyclones of High Velocity (over 500 miles in twelve hours) in the United States, 1893-1902. *Monthly Weather Rev., Washington,* **32,** 1904 (358-363 and 2 pl.).

Harding, C.—Scientific Balloon Ascents. *Aëronautical J., London,* **8,** 1904 (69-73).

Hegyfoky, J.—Die tägliche Drehung der Windrichtung. *Wetter, Berlin,* **21,** 1904 (193-199, 224-232).

Hennig, R.—Die Interessen der praktischen Witterungskunde an einem Island Kabel. *Wetter, Berlin,* **21,** 1904 (203-205).

Hepworth, M. W. C.—The Relation between Pressure, Temperature, and Air Circulation over the South Atlantic Ocean. *Symons' Met. Mag., London,* **39,** 1904 (170-171).

Herrmann, E.—Zur Giltigkeit der Ferrelschen allgemeinen Zirkulation der Atmosphäre. *Meteor. Zeits., Vienna,* **21,** 1904 (412-413).

Holdefleiss, P.—Die Abhängigkeit der Ernteerträge von den Witterungsfaktoren. *Wetter, Berlin,* **21,** 1904 (205-211, 237-240).

Homma, J.—Beiträge zur Kenntnis der Temperatur-verteilung in der Atmosphäre und ihrer Beziehung zur Witterung. *Meteor. Zeits., Vienna,* **21,** 1904 (453-458).

Hutchins, C. C., and Pearson, J. C.—Air Radiation. *Monthly Weather Rev., Washington,* **32,** 1904 (314-317).

Johnston, T. N.—The Bathymetrical Survey of Loch Ness. *Geog. J., London,* **24,** 1904 (429-430); *Scot. Geog. Mag., Edinburgh,* **20,** 1904 (589-590).

Jones, J. R. G.—The Wettest Spot in the United Kingdom. *Symons' Met. Mag., London,* **39,** 1904 (172-174).

Kienast, H.—Der Gang der Lufttemperatur in Konigsberg i Pr. *Wetter, Berlin,* **21,** 1904 (178-184).

Kimführ, R.—Über Wetterprognose. *Wetter, Berlin,* **21,** 1904 (199-202).

Koppen, W.—Über den zusammenhang zwischen der Stärke der Platzregen und ihrer Dauer. *Wetter, Berlin,* **21,** 1904 (169-177).

Lewis, F. J.—Geographical Distribution of Vegetation of the Basins of the Rivers Eden, Tees, Wear, and Tyne. Part II. *Geog. J., London,* **24,** 1904 (267-285 and 7 pl.).

Leyst, E.—Meteorologische Beobachtungen in Moskau in Jahre 1903. *Bull. Soc. Imp. des Natur., Moscow,* **1903.**

Lockyer, W. J. S.—Astronomy and Cosmical Physics at the British Association [1904]. *Nature, London,* **70,** 1904 (536-538).

Lydecker, R. C.—The Unusual Rainfall of February [1904] at Honolulu. *Monthly Weather Rev., Washington,* **32,** 1904 (363-364).

Mache, H.—Über die Geschwindigkeit und Grösse der Regentropfen. *Meteor. Zeits. Vienna,* **21,** 1904 (378-380).

Maclagan-Wedderburn, E.—Seiches observed in Loch Ness. *Geog. J., London,* **24,** 1904 (441-442).

Marconi Weather Telegrams. *Nature, London,* **70,** 1904 (396-397).

Masson, O.—On the Wetting of Cotton by Water and by Water Vapour. *Proc. Roy. Soc. London,* **74,** 1904 (230-254).

Meinardus, W.—Über Schwankungen der nordatlantischen Zirkulation und ihre Folgen. *Ann. d. Hydrog. u. Marit. Met. Berlin,* **32,** 1904 (353-362 and pl.).

Meteorology at the British Association, 1904. *Symons' Met. Mag., London,* **39,** 1904 (141-150, 161-172).

Mill, H. R.—On the Unsymmetrical Distribution of Rainfall about the Path of a Barometric Depression. *Symons' Met. Mag., London,* 39, 1904 (161-165).

Mill, H. R.—The Vengeance of the Rain Gods. *Symons' Met. Mag., London,* **39,** 1904 (181-185).

Moreno y Anda, M.—El decrecimiento de la temperatura con la altitud. *Mem. Soc. Cient. "Antonio Alzate," Mexico,* **19,** 1903 (137-157).

Moureaux, T.—Résumé de trente années d'observations météorologiques à l'observatoire du Parc Saint-Maur (1874-1903). *Ann. Soc. Mét. France, Paris,* **52**, 1904 (205-213).

Murray, Sir J., and Pullar, L.—Bathymetrical Survey of the Fresh Water Lochs of Scotland. *Scot. Geog. Mag., Edinburgh,* **20**, 1904 (449-459 and pl.); *Geog. J., London,* **24**, 1904 (546-569 and 5 pl.).

Nimführ, R.—Eine neue atmosphärische Storung. *Wetter, Berlin,* **21**, 1904 (190-192).

Nimführ, R.—Die Bedeutung des Drachens für die dynamische Meteorologie und die Wetterprognose. *Meteor. Zeits. Vienna,* **21**, 1904 (408-412).

Nippoldt, A.—Über die innere Natur der Variationen des Erdmagnetismus. *Meteor. Zeits., Vienna,* **21**, 1904 (393-399).

Noble, A.—Dust in the Atmosphere during 1902-3. *Monthly Weather Rev., Washington,* **32**, 1904 (364-365).

Outram, T. S.—Storm of August 20, 1904, in Minnesota. *Monthly Weather Rev. Washington,* **32**, 1904 (365-366).

Perlewitz, P.—Drachenaufstiege in ihrem Einfluss auf Gewitter. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (469-473).

Pettersson, O.—On the Influence of Ice-melting upon Oceanic Circulation. *Geog. J., London,* **24**, 1904 (285-333).

Polis, P.—Ergebnisse der Niederschlags-Registrierungen zu Aachen 1896 bis 1902. *Meteor. Zeits., Vienna,* **21**, 1904 (416-419).

Quinn, J. T.—The Movements of High Clouds in the West Indies. *Monthly Weather Rev., Washington,* **32**, 1904 (309-311).

Rahir, E.—Note sur une perturbation barometrique observée dans la caverne du "Höll-Loch" (Trou d'Enfer) à Muotathal (Suisse), ainsi que sur quelques constatations thermométriques. *Ciel et Terre, Brussels,* **25**, 1904 (338-340).

Reinicke, G.—Einfluss des Windes und Seeganges auf die Geschwindigkeit der Dampfer. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (451-457).

Resultate der meteorologischen Beobachtungen zu Swakopmund im Jahre 1903. *Meteor. Zeits., Vienna,* **21**, 1904 (428-429).

Réthly, A.—Starker Hagelfall zu Ó-Gyalla. *Meteor. Zeits., Vienna,* **21**, 1904 (388-389).

Return of the National Antarctic Expedition. *Geog. J., London,* **24**, 1904 (377-384).

Rotch, A. L.—The Temperature of Air in Cyclones and Anti-cyclones, as shown by Kite Flights at Blue Hill Observatory, U.S.A. *Symons' Met. Mag., London,* **39**, 1904 (172).

Schreiber, P.—Über die Beziehungen zwischen dem Niederschlag und der Wasserführung der Flüsse in Mitteleuropa. *Meteor. Zeits., Vienna,* **21**, 1904 (441-452).

Stade, H.—Die vierte Konferenz der Internationalen Kommission für wissenschaftliche Luftschiffahrt zu St. Petersburg, vom 29. August bis 4. September 1904. *Wetter, Berlin,* **21**, 1904 (217-224, 241-248, 274-282).

Stalköf, St. D.—Eine neue atmosphärische Störung. *Wetter, Berlin,* **21**, 1904 (232-235).

Stentzel, A.—Über die sogenannte "Temperatur des Weltraumes." *Meteor. Zeits., Vienna,* **21**, 1904 (371-375).

Stolberg, A.—Über die Bewölkungsverhältnisse von Strassburg i E. *Meteor. Zeits., Vienna,* **21**, 1904 (414-416).

Suggested Uniformity of Units for Meteorological Observations and Measurements. *Symons' Met. Mag., London,* **39**, 1904 (191-194).

Süring, R.—Bericht über die Ergebnisse der deutschen Wolkenbeobachtungen im internationalen Wolkenjahre. *Meteor. Zeits., Vienna,* **21**, 1904 (358-371).

Talman, C. F.—Recent Contributions to Climatology. *Monthly Weather Rev., Washington,* **32**, 1904 (368-369).

Thomas, J. L.—Two Cases of Lightning Stroke. *Brit. Medical J., London,* **1904** (1155-1159).

Vanderlinden, E.—L'année des nuages. *Ciel et Terre, Brussels,* **25**, 1904-5 (425-432, 449-457, 511-518).

Waite, P. C.—The Annual Rise and Fall of the Nile. *Scot. Geog. Mag., Edinburgh,* **20**, 1904 (474-489, 543-544).

Watson, E. R.—Movements of the Waters of Loch Ness, as indicated by Temperature Observations. *Geog. J., London*, **24**, 1904 (430-437).

Watson, E. R.—On the Ionization of Air in Vessels immersed in Deep Water. *Geog. J., London*, **24**, 1904 (437-441).

Wegemann, Dr.—Erweiterung des barischen Windgesetzes nebst Anwendungen. *Ann. d. Hydrog. u. Marit. Met., Berlin*, **32**, 1904 (408-415).

Willsea, J. B.—Detailed Cloud Observations in Colorado. *Monthly Weather Rev., Washington*, **32**, 1904 (116).

Wilson, W. E.—Peculiarities in Barograph Curves characteristic of Approaching Storms. *Proc. R. Irish Acad., Sect. A, Dublin*, **25**, 1904 (1-2).

Woeikof, A.—Nachtrag zu den Problemen der Bodentemperatur. *Meteor. Zeits., Vienna*, **21**, 1904 (399-408).

Zahm, A. F.—The Measurement of Air Velocity and Pressure in Aërodynamic Experiments and the Balloon Anemometer. *Aëronautical J., London*, **8**, 1904 (74-81).

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

VOL. XXXI.] APRIL 1905 [No. 134

THE CONNECTION OF METEOROLOGY WITH OTHER SCIENCES.

BY COMMANDER D. WILSON-BARKER, R.N.R., F.R.S.E., F.R.G.S., President.

[An Address to the Royal Meteorological Society, January 18, 1905.]

METEOROLOGY and Astronomy were doubtless the first of the sciences to attract the attention of men: which of the two exerts most influence on the well-being of humanity is a matter dependent on location. In many regions people are but slightly affected by the weather, while the heavenly bodies, particularly the sun, have an enormous influence on human life. But although Meteorology must have been of importance from the earliest times, it has only recently taken its place in the circle of studied sciences. Its long neglect may have been due to the great difficulties in the way of grappling with its complicated and baffling problems. We live at the bottom of the atmosphere, of which our knowledge, at present, is confined vertically to a very short distance above our level. We are, however, surely, if slowly, gaining information of the nature and action of the upper regions of the air: we know that it permeates everywhere, and that it profoundly affects almost every physical action.

It is proposed in this Address to review briefly the bearings of Meteorology on some of the other sciences. The influence of one science on another is often great, but I think none is so universal in its action as Meteorology, so that some comprehension of its workings would seem to be a necessity for the specialist in any branch of science.

Everywhere in Nature we find the effects of meteorological agencies. Water is taken from one place to be deposited elsewhere. All water comes from the sea, and to the sea it is eventually returned; but in the intervening stages, through what changes and chemical evolutions does it not pass! The absorption of heat in its evaporation; its passage through the atmosphere, either as invisible vapour or as cloud; its deposition on

the mountains or on the plains in the form of rain, hail, or snow; the effects these different forms have on the surface on which they rest, the percolation of water into the soil taking with it various solutions of atmospheric gases and other chemical substances; its collection in wells or streams; and, finally, its return to the sea, to recommence its eventful course—all are phases in a wonderful history well worth greater attention than they ever receive.

The wind, with its never-ending variations of force, is another powerful transforming agent in Nature. Sometimes it carries dust particles along in such quantities as to form a strong eroding instrument; or the wind will clothe the land with sand, so as to entirely

D. W.-B.

FIG. 1.—Mer de Glace, Switzerland.

alter the appearance and the habitable conditions of a country. How floods may be caused by wind was brought home to the dwellers by the Thames on December 30, 1904, when, right in the middle of the neap tides, the prevalence of a Northerly gale caused the river to rise in places to such heights that it overflowed its banks and considerable damage, much loss, and great discomfort, though not actual loss of life, ensued. The flood occurred without warning, as did one on a previous occasion, November 29, 1897, in similar wind conditions.[1] In the present state of our knowledge of wind and its results, it would be almost impossible to forecast floods such as these; but when rain or snowfall is in question, very successful forecasts are possible, as is abundantly proved by the work done in this direction in the United States. The Institution, which so kindly permits us to use this theatre, has always been most generous in its recognition of the importance of Meteorology, and of its bearing on the work of the Civil Engineer.

Geology.

The influences of Meteorology are most evident to the geological observer. We have the effects of vapour deposits in the shape of rain, ice, snow, and the floods and the damage they occasion, and, on the other

[1] A depression moved south-east over the North Sea.

hand, their beneficial results, in the nutritious mud deposits, etc., which they leave over extensive areas. The plains surrounding the Amazon and the Nile are probably the districts most affected by flood. These inundations have, at different epochs of the earth's history, been re-

D. W.-B.

FIG. 2.—Reef at Pernambuco.

sponsible for much destruction of life. Large collections of animal remains have been discovered (the mammoth in Siberia and the moas in New Zealand may be instanced), showing probably that, at one time or another, heavy rains have caused the sudden overflowing of rivers and the overwhelming of animals by the waters before they could escape.

M. LYON MACKENZIE.

FIG. 3.—Earth Pillars, Switzerland.

From snow action we get the great glaciers (Fig. 1) which carve out valleys (the exact process is a matter of dispute among geologists) and carry débris from one district to another, and which in the Arctic regions make many tracts practically impenetrable.

Rain has played an important part in the fixing of coral reefs: the

rain-water dissolves some of the constituents of the coral, which penetrates in solution into the coral rock and hardens it. On the reef at Pernambuco, which is really composed of sand and mud, the detached corals and other remains of dead organisms get dissolved, cement together, and form a hard surface, which rings when struck with a hammer. The Pernambuco

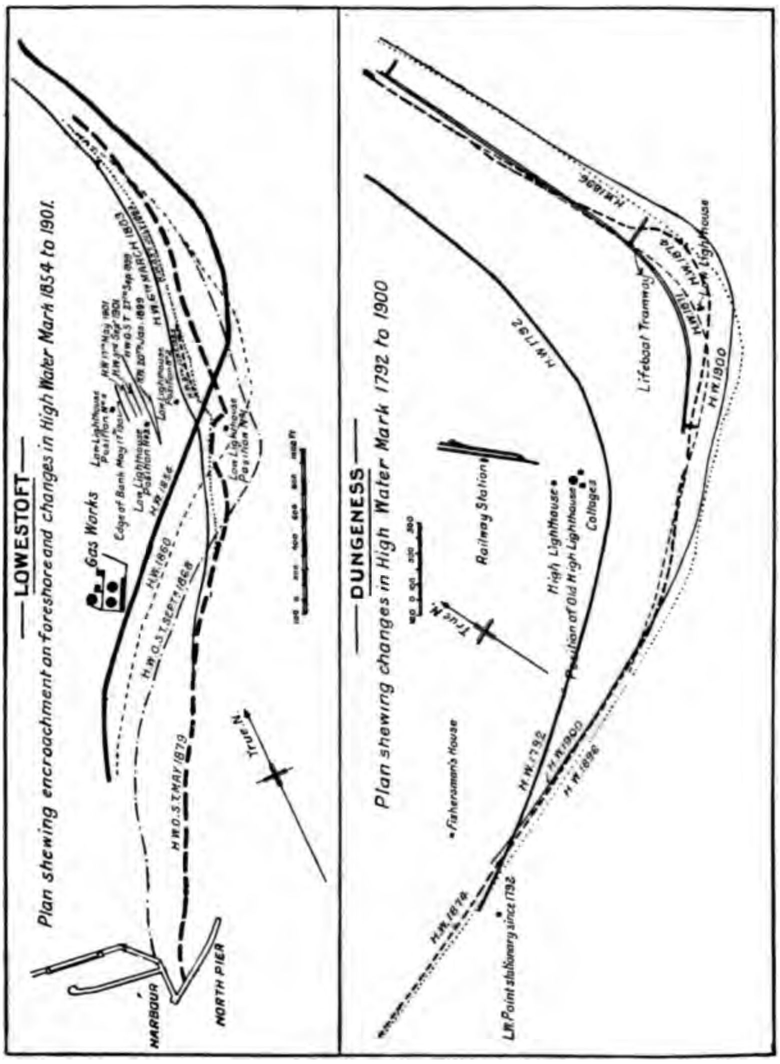


FIG. 4.

reef (Fig. 2) is characteristic of those that line the coast of Brazil for some distance north and south, and are the combined results of wind action and the collection of detrital matter washed down in the rivers to the sea. On some islands the effect of rain-water is to be found in the rich phosphatic rocks of guano deposits through which the rain percolates. In other cases rain wears down the rocks and carries away the detritus

FIG. 5.—Upper Glacier, Grindelwald. D. W.-B.

FIG. 6.—The Lütschine. D. W.-B.

FIG. 7.—Lake Thun. D. W.-B.

Figures 5, 6, and 7, illustrate the formation of a river, the Lütschine, from its source the upper glacier (5) at Grindelwald, to the river itself (6), and its termination (7) in Lake Thun.

to deposit it over fresh surfaces. The denudating influence of rain is strikingly illustrated by the well-known "earth pillars" (Fig. 3) which are common in some districts: their peculiar formation is due to the fact that certain portions of the soil are protected by stones or other hard material from being washed away with the surrounding earth.

FIG. 8.—Peak, Fernando de Noronha. D. W.-B.

FIG. 9.—Peak, Fernando de Noronha. D. W.-B.

Figures 8 and 9 show the effects of denudation on the remarkable Peak of Fernando de Noronha (1000 feet high); all the softer rocks being washed away leave the central phonolite core.

Atmospheric action is best studied on a sea coast, and more particularly on the coasts of our own country. The sea, under the influence of the wind, is constantly altering the conditions and the aspect of the shore. The chart thrown on the screen illustrates better than any verbal description the eroding agency of the sea, as noticed off the coast of Lowestoft, where it has been necessary to shift the position of the lighthouse four

times in forty-seven years (Fig. 4). On the other hand, in other directions, as on the south-east coast, off Dungeness, the weather influences combined with the tides have had the contrary effect, and the land gains rapidly from the sea.[1] Similar alterations and transformations are constantly going on elsewhere, though sometimes so slowly as to be almost imperceptible.

The most powerful atmospheric agent in some countries is snow, which forms avalanches and glaciers carrying sometimes, in sudden rushes, all before them, and in other cases slowly grinding up rocks and causing a fresh distribution of surface soil over certain districts (Figs. 5, 6, and 7).

FIG. 10.—Africa.

The geological nature of the strata largely controls the denudation process always at work, and is the cause of the wonderfully diversified and picturesque aspects of landscapes (Figs. 8, 9).

In tropical countries the rock-splitting action of great heat is noticeable: rocks break up with the sudden fall of the temperature at night, and by degrees they crumble away into dust-heaps; the wind blows these on to adjoining rocks, which it carves out and polishes, so that very curious formations of rock surfaces result (Fig. 10).

There are many instances of vast areas of land owing their characteristic features entirely to the influence of meteorological agencies. I need but mention the "Bad Lands" of the United States, the Sahara and the Kalahari deserts, and the great deserts of Central Asia and Australia.

Geologists have advanced various theories to explain great climatic changes, but they would appear to err in so far that they invariably approach the subject from the geological standpoint, whereas such problems are much more likely to find solution by the aid of meteorological investigations. There are many difficulties, and the conflicting nature of the subjects to be investigated is constantly baffling. For instance, the vegetation assumed to be indigenous to temperate or tropical regions may be found among glacial conditions, and so with other forms

[1] I am specially indebted to Mr. Thomas Matthews, C.E., the Engineer to the Trinity House, for these interesting cases.

of life. Butterflies are commonly seen in the Alps flitting about the edges or even in the middle of a glacier. Flowers bloom in these inhospitable quarters. I have found small moths and plants far above the snow-line existing mysteriously in spite of bitter cold and strong winds, on almost completely bare rocks.

Zoology.

The influence of Meteorology on animal life is all pervading. One of the most common results is the winter sleep (hibernation) of the dormouse, the polar bear, and other animals; and the summer sleep (æstivation) of some fishes (Polypterus) and reptiles. It is a curious fact, that in the state of hibernation animals can exist without oxygen, and in conditions that would be fatal at other times. The weather regulates the migratory habits of birds and insects, and it is probably the cause of the occasional mysterious and unexpected appearance of great numbers of insects—at other times rare. An explanation of such phenomena would be welcome. Many well-known sayings attest the susceptibility of animals to weather—a susceptibility increased by the hygroscopic tendency of their hair or feather covering. In coral reefs, reproduction and growth seem dependent on an even and warm temperature of the water and air. In fact, temperature is a powerful factor in the reproduction of most forms of animal life, and experiments in this direction have elicited some curious facts. The instance of aphides may occur to many. Incessant wet has a most injurious effect on ground life such as larvæ, pupæ, etc. These seem, however, to be but little affected by cold, and it would appear that steady, seasonable temperatures are invariably good for them, but sudden and severe changes are fatal. The young of game, and of all birds and animals that breed on the ground, are similarly affected.

The effects of changes of climate on fish and sea organisms generally have not yet been ascertained, but the investigations being carried on by Dr. Dickson, Dr. Mill, and others, in connection with the Biological Association studies, are likely to give interesting results, and, as far as they have gone, undoubtedly show that meteorological conditions do largely control the abundance of fish.

Agriculture.

Agriculturists are more dependent on the weather and more interested in the development of its study than any other class of persons. It may be argued that a man should regulate his farming operations and his crops in accordance with the prevailing weather conditions of his country and district; but this is not always possible: land suitable for one crop may not do for another, and an unexpected wet or dry season may destroy the cultivator's best laid plans. Were it possible to furnish certain forecasts a reasonable time ahead, farmers would be much benefited. They might help themselves in a great measure by paying more attention to the weather signs and portents of their immediate neighbourhood, instead of trusting, as they do, to chance, or to the official forecasts published, forgetting that these are necessarily general and not local in their indications, and applying to wide districts as a whole. Rain is the great friend and sometimes the bitter enemy of the agriculturist. He depends on it for the watering of his crops, and for the humidity which helps his farm-

ing and breaks up and percolates his land. We need only remember Australia, the great wool-producing country of the world, to realise the losses occasioned by the want of rain. As a consequence of drought, the bales of wool shipped to this country from Australia in the year ending June 1904 were but 994,796 as against 1,267,936 bales for the year ending June 1902, and 1,595,652 bales in June 1895. The country is only beginning to recover from the effects of that shortage. Land may be dressed with all the best available materials, but without the dissolving action of the rain, combined with its percolation into the soil, top dressings are of little use.

Rain communicates to the soil certain atmospheric constituents: nitrogen, for instance, is probably conveyed to the earth in this way, and the comparative richness of the soil in rainy districts may be due to this fact, which is not noticeable in ordinary analyses. It is a moot point whether plants obtain their nitrogen principally from the earth, or from the air; but it seems probable that both air and earth contribute the supply, which is assimilated through the agency of various micro-organisms.

The seeds of many varieties of plant life are specially adapted for wind carriage, and the different means by which they are dispersed is a fascinating subject of study. On the other hand, many trees act as protectors to vegetation from the violence of the wind, and also serve to bind the soil together. Vegetation affords a powerful protection to some rocks; others are slowly broken up by the roots which penetrate the crevices. There are curious differences in the growth of the giant trees of Australia and California, of which I have never seen an explanation. In the former case they run up to the height of 300 to 480 feet, and are practically branchless till the summit is reached; in the latter case, the trees are well branched all along their length. It would be interesting to know if climatic influences account for the difference.

Phenological work will one day yield a rich harvest. The fine series of observations collected by the Rev. T. A. Preston and ably continued by Mr. Mawley might be thoroughly discussed with great benefit to this branch of study, regard being paid to the meteorological conditions prevailing at and around the places of observation. The work was started long ago by Alphonse de Candolle, and is waiting to be carried on by a greater number of able observers. Co-operation between agriculturists and meteorologists over large areas would appear to be the most promising system of work. There are many difficulties, financial and otherwise, in the way of organised work and the collection of statistics for any length of time; but the difficulties are not insurmountable, and the resultant benefit to the country should be great.

Hygiene.

The effect of weather upon health has not received a fair amount of scientific notice. With a few exceptions, doctors give Meteorology small attention in their consideration of health conditions. It is certainly difficult to distinguish between direct and indirect weather influences on the human organism. Dr. E. G. Dexter has recently collected observations on the subject; Dr. Theodore Williams, Sir John W. Moore, and the late Dr. Marcet, all of this Society, have given special attention to the subject. It is certain that many people who suffer from weather

causes are yet not particularly sensitive to, or conscious of, the presence of injurious conditions. All can appreciate the difference in the air-pressure at the foot and on the top of mountains, and at the surface and at the bottom of a mine. It is reasonable to suppose that the changes in pressure experienced by the passage of cyclones and anticyclones also affect us. We must remember that changes in pressure on the square inch may vary in twenty-four hours from 14¾ lbs. to 14¼ lbs. or even more. Something of this kind may be the cause of mountain sickness.

I am often surprised that the ability of the human body to maintain an equable temperature under all climatic conditions attracts so little notice. The capacity is specially marked in tropical climates, where the air temperature for days is often higher than that of the blood. Weather influences on constitution may be more profitably studied in tropical climates than elsewhere.

The electrical condition of the atmosphere is a potent factor in well-being. This influence is the most subtle and the most difficult to detect, but I am inclined to attribute more importance to it than to other weather causes. The present methods of detecting atmospheric electricity are most imperfect.

The direct effect of the sun's rays is but little understood. In tropical countries they are avoided as much as possible, and their results elsewhere are chiefly noticed by the production of freckles or tan. It is interesting to remark that the reflected sunlight from the sea surface is much more effective in the production of tan than is the direct sunlight.

The transmission of disease germs is a matter of the greatest hygienic importance. Whether disease germs can be carried in the air or not, is an undecided point which ought to be closely investigated. In cases of hay fever we find some people particularly subject to irritation and inflammation of certain glands, which are affected by fine forms of matter present in the air when the grass is ripe for cutting, but the great majority of people escape the complaint altogether. While moisture seems to help the propagation of minute organisms and microbes, cold, even immersion in liquid air, seems to exert but a dormant influence on them. Intense heat alone, procurable by artificial means, is able to destroy them.

Difficulty of investigation is increased by the fact that we live in a germ-filled atmosphere, in which experiments cannot easily be approached in sterilised conditions.

Many invalids benefit by removal to suitable climates, and if the medical profession would co-operate more fully with meteorologists, and pay more attention to the connection of climatic causes with physiological effects, humanity might derive much benefit. The healthy human being can adapt himself to any climate, can be well anywhere and not feel diminution of energy in the carrying on of the ordinary functions of life, although subject to much discomfort and inconvenience from heat in the tropics and from cold in the polar regions.

It is a curious fact that while Medical Officers write voluminous reports on the public health, from almost every point of view, nearly all of them ignore the meteorological conditions of the districts under review, although such conditions may possibly have a powerful influence in the matter of checking or spreading of epidemics and other illnesses.

Conclusion.

I hope I have shown that Meteorology is a science deserving more attention than it receives. I think it ought to be recognised as a preliminary to the studies of Geography, Geology, and kindred subjects. Every one has opportunities for the observation of the weather, and every one is interested in it; but I think meteorological observatories might very well be fitted up in schools, and pupils taught to observe. This could be done at small cost of time or money.

The tendency at present is to particularise in all scientific work, but the true path to progrèss lies in keeping a comprehensive outlook on the whole wide field of investigation. The United States have devoted much attention to Meteorology, with most satisfactory results. It is to be regretted that official help and encouragement are so backward in this country. The baffling, difficult nature of meteorological problems should but serve as an incentive to their elucidation. The persistent observer gains much, not only in knowledge of the subject, but in the habits of close and accurate investigation which he insensibly acquires; and all workers in this field learn to appreciate the difficulties which confront their fellow-labourers, and to recognise the value of what has been done by the meteorological bureaux of the world.

In bringing these facts before you, I wish to emphasise the importance of the subject, and to indicate some points for the attention of would-be workers, to whom I can at any rate promise that an inexhaustible stock of interesting matter awaits their labours and investigations.[1]

Sydney Observatory, New South Wales.

During the absence of Mr. Russell, the Government of this State decided to temporarily sever the Meteorological from the Astronomical Department, and on January 20, 1904, appointed Mr. H. A. Hunt to the office of Acting Meteorologist.

On February 22 the Acting Meteorologist sent a circular to each of the most important national weather services in other countries inquiring as to their methods and aims. To which the directors of these different services courteously responded, giving very full information. On June 29 a lengthy report was compiled embodying the result of these inquiries, together with suggestions for the improvement of our present service, and forwarded to the Hon. the Minister for Public Instruction in this State. It is hoped that these recommendations may receive favourable consideration.

On February 29 our Department of Public Instruction issued a new Educational Syllabus, which provided for the inclusion of Meteorology in the list of subjects taught in our schools. Since the advent of this new syllabus the Meteorological Department has received a great many applications from teachers for hints bearing upon Meteorology and for instruments. Unfortunately we have been unable to accede to the latter request owing to shortage in funds, and the Public Schools Associations in the country districts of this State then made an appeal to the Sydney *Daily Telegraph* for the daily publication of isobaric charts, in order that these might be used for instruction in the schools, to show the connection between the distribution of pressure and different phases

[1] The Address was illustrated by a number of lantern slides, for many of which relating to Geology I am indebted to Professor Garwood and also to the Royal Geographical Society.

of weather. The *Daily Telegraph* then applied to this department for such a chart, asking that the information be supplied to them not later than 2 p.m., in order that the map might appear in their evening country editions, so that these might be available for use in the schools on the following day. We very cordially responded, and an isobaric chart, together with arrows showing the direction of the wind, and shaded areas the rainfall, etc., has been a regular feature in this enterprising journal since October 11th. The Sydney papers each day give a large amount of space to weather items, sometimes running into several columns, as in the case of special rainstorms, and we are much gratified to notice a steadily growing interest in meteorological questions. We believe that by the publication of their isobaric chart the proprietors of the Sydney *Daily Telegraph* are doing the cause of Meteorology a great service in Australia, because the children now taught in our schools, where these charts are used for demonstration purposes, will probably grow up with a more sympathetic bearing towards Meteorology than their parents at present have.

1. Forecasting and Map-Compiling under the Acting Meteorologist.—Two weather charts have been prepared daily: the first contains a *résumé* of what data have been received, together with forecast, and goes to press at 1 p.m. The second contains complete data, isobars, very full notes, and forecast for the ensuing 24 hours, and is published at 4·30 p.m. During the year 22,100 such charts have been published, which shows an increase of 4100 over the amount noted in our last annual Report. Of these charts 20 have been distributed daily to the different public offices and newspapers, and 24 have been posted daily to the chief country towns in our State. Forecasts have also been telegraphed each day at 4.30 p.m. to 63 stations in New South Wales. In addition to the above, 4112 charts showing the daily rainfall, and 888 showing the monthly rainfall and percentages over New South Wales, have been published and distributed throughout the city and to different country centres during the year. These maps are also reproduced from the Observatory original by a private firm in the city for distribution amongst subscribers.

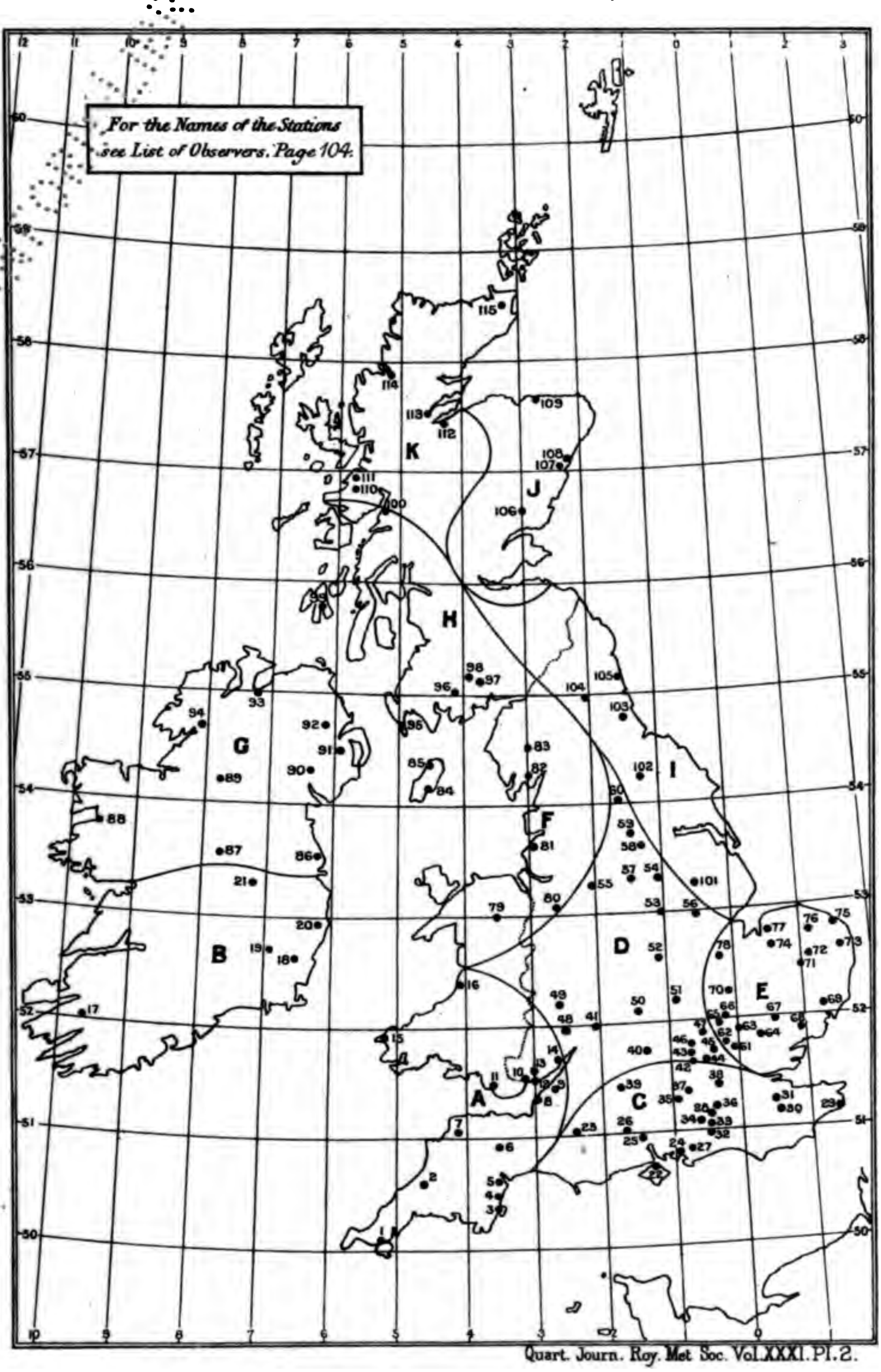
2. Climatological Branch under Mr. A. Noble.—During the year 56 new stations have been added, bringing the number now reporting up to 1903 stations. All these are equipped with rain gauges, and 1863 furnish returns monthly, and the remaining 40 at the end of the year.

It was noted in our last annual Report (vol. **30**, p. 181) that the manuscript for the years 1901 and 1902 had been forwarded to the Government printer. We regret to state that the Reports are not yet out of press. Meanwhile publication of the results for the years 1903 and 1904 will have to remain in abeyance.

A very useful publication containing the monthly results of all the meteorological elements at about 200 of the best equipped stations in this State was brought out under the auspices of this Observatory at the close of each year down to the year 1890, but shortage in funds has prevented the regular issue of this annual volume since that year, although all the manuscript for these subsequent years is ready for the printer. In view of this fact, representation was made in April 1904 to the Hon. the Minister for Public Instruction in this State, who sanctioned the publication of these results for the years 1891 to 1895, inclusive, for which years the MSS. are at present in the hands of the printer. It is hoped that the publication of such valuable data may soon be brought up to date.

A monthly review of the weather over Australia generally has been prepared since August 1904, tracing the progress of the different changes in atmospheric pressure and their effect upon the weather. Copies of this review are sent to each of the daily papers, the Agricultural Department, and to the Government Statistician.—H. A. LENEHAN, *Acting Government Astronomer.*

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1904.



REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1904.

By EDWARD MAWLEY, F.R.Met.Soc., V.M.H.

(Plate 2.)

[Read February 15, 1905.]

THE following changes have taken place in the observing stations since the last Report was issued. No returns were received during the year from Liskeard and Westward Ho in District A; Skibbereen in District B; Market Weston in District E; Scaleby in District F; Ramelton in District G; and East Layton and Lilliesleaf in District I. On the other hand, new stations have been started at Starcross in District A; St. Albans (New Farm) in District D; Roxton and Southacre in District E; Birkdale (Southport) in District F; and Milford in District G. The total number of observing stations is now 115.

The averages with which the mean dates of the different plants are compared in Table IV. have been obtained from the actual observations made during the 14 years 1891-1904 in all those districts where sufficient observations were available. Those for the remaining districts are as near approximations to the true averages as the limited number of records will allow.

TABLE I.—MEAN RESULTS, WITH THEIR VARIATIONS FROM THE 14 YEARS' AVERAGE (1891-1904), FOR THE THIRTEEN PLANTS IN THOSE DISTRICTS WHERE THERE HAVE BEEN SUFFICIENT OBSERVATIONS TO WARRANT COMPARISONS BEING MADE.

YEARS.	Eng. S.W.		Eng. S.		Eng. Mid.		Eng. E.		Eng. N.W.	
	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.	Day of Year.	Variation from Average.
		Days.		Days.		Days.		Days.		Days.
1891	144	+10	144	+ 9	150	+11	147	+10	150	+ 6
1892	139	+ 5	138	+ 3	144	+ 5	143	+ 6	147	+ 3
1893	118	-16	122	-13	125	-14	123	-14	128	-16
1894	126	- 8	130	- 5	135	- 4	127	-10	137	- 7
1895	139	+ 5	138	+ 3	141	+ 2	138	+ 1	144	0
1896	125	- 9	128	- 7	132	- 7	130	- 7	134	-10
1897	130	- 4	132	- 3	136	- 3	132	- 5	142	- 2
1898	133	- 1	135	0	138	- 1	136	- 1	141	- 3
1899	136	+ 2	136	+ 1	141	+ 2	138	+ 1	145	+ 1
1900	142	+ 8	141	+ 6	144	+ 5	143	+ 6	152	+ 8
1901	138	+ 4	139	+ 4	141	+ 2	139	+ 2	144	0
1902	139	+ 5	140	+ 5	145	+ 6	142	+ 5	152	+ 8
1903	134	0	134	- 1	137	- 2	134	- 3	145	+ 1
1904	139	+ 5	139	+ 4	142	+ 3	140	+ 3	149	+ 5
Mean	134	...	135	...	139	...	137	...	144	...

Explanation of the Dates in the Tables.

1- 31	are in	January.	183-213	are in	July.
32- 60	,,	February.	214-244	,,	August.
61- 91	,,	March.	245-274	,,	September.
92-121	,,	April.	275-305	,,	October.
122-152	,,	May.	306-335	,,	November.
153-182	,,	June.	336-366	,,	December.

The Winter of 1903-4.

Taken as a whole, this was rather a cold winter. During December and February the temperature was below the average in nearly all parts of the country, whereas January proved everywhere a mild month. The fall of rain was deficient in December, but in excess of the mean both in January and February. There was a paucity of sunshine in each month of the quarter, and particularly in February. If we except the north of Scotland, the deficiency ranged from − 42 hours in the north-west of England, to − 73 hours in the east of Scotland.

Seldom has there been a winter so unfavourable to the agriculturist. As stated in the previous Report, owing to the wet autumn, and other causes, there were few occasions after the middle of November when the cultivation of the land for winter corn could be proceeded with. So that if ever a dry time was wanted to make up the arrears of work, it was during the early part of this season. Whereas, until it was too late in December for sowing purposes, rain fell almost without intermission. During the rest of the winter, with the exception of the latter half of December and the last week in February, there were no periods of dry weather. Consequently, during that time the ploughing of the land for spring corn was either impracticable or carried on under very unfavourable conditions. It was not so much the heaviness of the rainfall at any one time as its remarkable persistency which proved so trying. The ground had become so sodden that even during the short spells of comparatively dry weather the least additional rain that fell upon it rendered it sticky on the surface—except in the case of very light soils. In the north of Scotland, where the rainfall was light, the hindrance came in the form of frosts and snow. Consequently, at the end of the winter the arrears of seasonable work were almost everywhere very considerable.

The frost and heavy rains at the beginning of December destroyed most of the flowers which were out in the gardens at the end of the autumn. The milder conditions which followed, however, favoured the excellent winter supply of green vegetables. This proved a very unfavourable season for planting fruit and other trees and shrubs, owing to the continued rain and the saturated condition of the ground. Such winter-flowering plants as the winter aconite, snowdrop, and crocus came into blossom rather in advance of their usual dates.

The fertile flowers on the hazel made their appearance, taking the country as a whole, one day later than usual, while the coltsfoot was 6 days late.

The song-thrush was first heard after the beginning of January, 9 days in advance of its average date.

The Spring.

The mean temperature of this season was rather below the average, but, as had been the case during the winter months, there were many moderately warm days, and at no time any exceptionally cold nights. In most districts the rainfall was rather light. On the other hand, in the north and west of Scotland the total fall was much in excess of the average, especially in April. There was again very little sunshine, the deficiency

for the southern half of the United Kingdom ranging from – 52 hours in the Midlands, to – 99 hours in the south-west of England.

The frosty weather at the end of February and beginning of March helped to make the soil a little more workable than it had previously been, but a few inches beneath the surface it still remained in a saturated condition. The dry weather which followed, however, gradually began to take effect, so that the preparation of the land for spring corn was from that time carried on with but few interruptions. A little later on steady progress was made with the drilling of this cereal, but the tilth that had been obtained was in many instances by no means all that could be wished. During April there occurred a welcome change to warmer weather, and the accumulated arrears of work were steadily overtaken, and before the end of that month, except in the more backward districts, a large quantity of spring corn had been sown. Farmers were also enabled to get in their potatoes and proceed with the cultivation of the ground for the reception of mangold seed. During the first half of April the weather proved very unfavourable in Scotland, owing to the heavy rains which had set in there, but after a short time the conditions appear to have been almost equally favourable everywhere. The rainfall, although moderate in quantity, was so evenly distributed over the season, that all crops were benefited by it, and towards the end of the spring the appearance of most kinds of farm produce had very much improved. The two great defects of the season were the legacy of sodden ground left by the winter, and the paucity of sunshine to warm the soil as the season advanced. The grass made but very little growth until the beginning of May, from which period, assisted by timely rains, good progress was made, so that at the close of the season there appeared every prospect of an excellent crop of hay, with good undergrowth.

The wet state of the soil at the beginning of the quarter interfered with the working of the ground and its preparation for spring seeds, but in April and May the weather was on the whole as favourable as could be desired. The season was noteworthy for the absence of anything like severe frosts, and also for the comparative freedom of all young growths from the attacks of aphis. The fruit blossom, which came out later than usual, appears to have been everywhere abundant, and many observers note more particularly the vigour and profusion of the apple blossom.

The wild flowering shrubs and trees, with few exceptions, also flowered with unusual freedom.

All the spring plants on the list flowered later than usual, the wood anemone being 4 days late, the blackthorn 7 days late, the garlic hedge-mustard 5 days late, the horse-chestnut 3 days late, and the hawthorn 6 days late.

Of the spring migrants included in the Report the swallow and cuckoo were both 1 day late, the nightingale 2 days early, and the fly-catcher 4 days late.

The honey-bee visited flowers 4 days behind its usual time, while the wasp was 15 days late, the small white butterfly 9 days late, and the orange-tip butterfly 6 days late.

The Summer.

July was in nearly all parts of the country a very warm month, but during June and August the mean temperature was rather below the average. The total rainfall varied a good deal in the different districts,

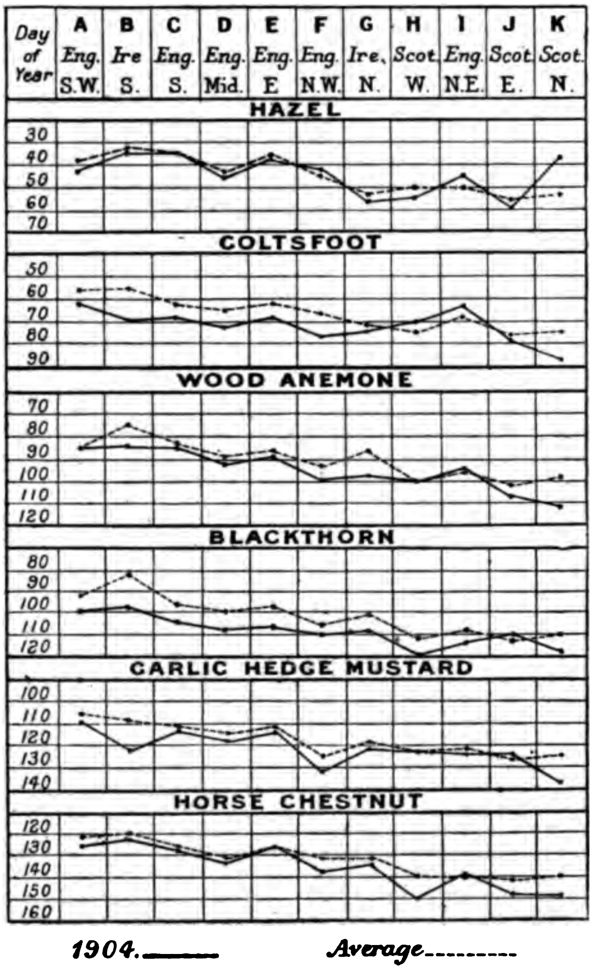


FIG. 1.

but in all of them, except those in Ireland, this was more or less a dry summer. It was also in most districts an exceptionally sunny one.

The hay harvest was an abundant one, and the crop was gathered in with little trouble, and in exceptionally good condition. Even in Scotland the greater part of the hay had been harvested before the end of July, which is very unusual. The long period of dry weather in June and July, while favouring the hay harvest, soon began to be felt by all the growing crops, when, added to the drought, came in July three weeks

of high temperature. The late sown cereals were amongst the greatest sufferers, but even in the case of those which were well established the ripening of the grain was unduly hastened, and was consequently prevented in many cases from becoming properly matured. The root crops were also seriously affected, while the pastures became bare. The

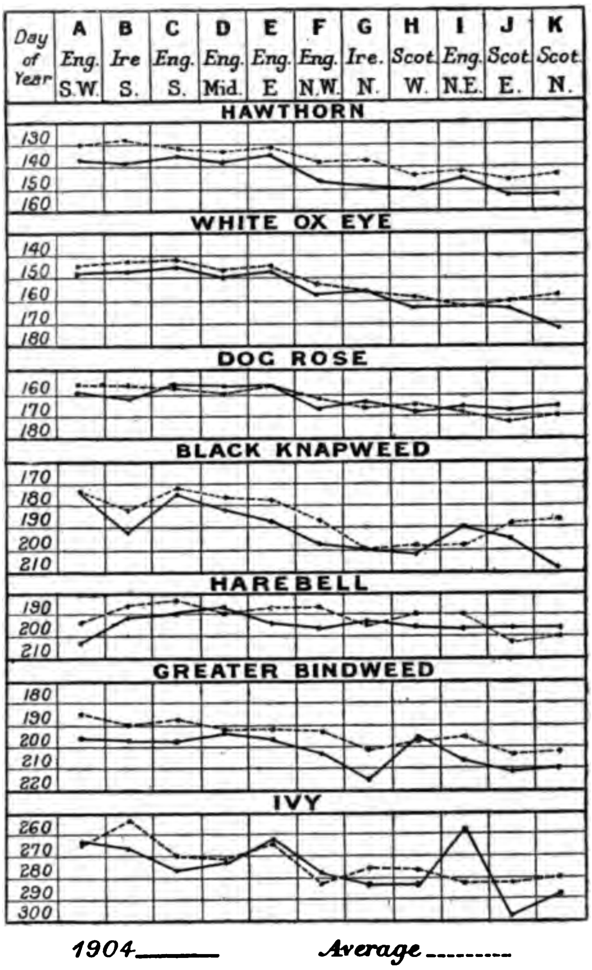


FIG. 2.

corn harvest came on rapidly in the earlier districts, and proceeded with little interruption throughout the whole of August. At the end of that month came some heavy rains which, falling as they did upon the warm ground, soon altered the appearance of the landscape. So greatly were the roots and grass benefited, that shortly after the close of the season there appeared every prospect of a fairly good root crop, and plenty of autumn feed in the recently bare pastures. In Ireland the conditions were much more favourable, as there seems to have been there no

complaints of drought, and consequently the roots and potatoes advanced without any check at all from dry weather, while at no time was there any lack of keep in the pastures.

All went well in the garden until after the first week in July, when the dry and forcing weather caused the growth of almost everything to be arrested by the drought. In August, owing to the check all plants and garden crops had thus received, and the many cold nights of that month, very little progress was made until the return of warmer and moister weather at the end of the summer. In the early part of the season the blossom on most kinds of flowering shrubs was unusually abundant.

All the summer-flowering plants on the list, except the dog-rose, which flowered at its average time, were late in coming into blossom, the white ox-eye being 4 days late, the black knapweed 5 days late, the harebell 4 days late, and the greater bindweed 7 days late.

The meadow-brown butterfly made its appearance 12 days later than usual.

The Autumn.

October was everywhere a warm month, but in September and November the mean temperature was in most districts rather low. In all three months there was a deficient rainfall. In fact, leaving out the north of Ireland and the north of Scotland, the deficiency ranged from − 3·1 ins. in Ireland south, to − 4·8 ins. in Scotland east. September proved remarkably sunny, but in the other two months the records were very variable.

Harvest operations proceeded everywhere, even in the colder parts of the country, with but little hindrance from wet weather, except in Ireland, where the interruptions from that cause during the third week in September proved for a short time rather troublesome. The ingathering of the corn was, however, practically over in all but the latest districts by the end of September. Seldom has there been a harvest when less corn was lodged, or when so little grain sprouted, or was shed. The continuance of fine weather, with occasional rains to moisten the surface, enabled the ploughing and cleaning of the stubbles to be begun at an unusually early date, and to be carried on almost without a break during the rest of the season. The tilth afterwards obtained for sowing winter corn, owing to the baking the ground had received during the summer, was excellent. An opportunity was at the same time given for clearing the land of weeds, of which there was a large accumulation, due to the impossibility of dealing satisfactorily with them during the previous autumn, winter, and spring. The sudden, and in places remarkably severe frost, generally accompanied by falls of snow, which occurred during the third week in November, was felt in most districts, and particularly in the north of England, Ireland, and Scotland. Beyond destroying here and there the roots of mangolds which had not been taken up and stored, this frost does not seem to have done much damage—doubtless in some measure owing to the protection afforded to the other crops by the snow. During the autumn the root crops improved beyond all expectation, while there was always a good crop of herbage in the pastures.

For the gardens this was also a very favourable season, and up to

the time when the sudden frost above referred to occurred, they were unusually gay with flowers. As shown by our observers, the number of autumn flowers and survivals from the summer was, previous to that frost, unusually large. In the kitchen garden the winter crops of green vegetables made steady, and sturdy, growth, while the planting of fruit and other trees could be carried out under the most favourable conditions both of soil and weather.

The timber trees, owing to the moist condition of the subsoil, made good growth, while the foliage on them was unusually luxuriant. Wild fruits such as acorns, blackberries, haws, etc., were remarkably plentiful. As in the previous year the weather conditions seem to have been less favourable to insect life than usual. There were but few wasps or butterflies, while bees produced but little honey. The autumn tints were everywhere singularly fine.

The only autumn plant on the list, the ivy, came into flower 2 days later than usual.

The mean date for the departure of the swallow was 4 days early.

According to the *Preliminary Statement for Great Britain*, issued by the Board of Agriculture, the yield per acre of wheat was below the average for the previous 10 years by as much as 4·13 bushels (the lowest since 1895), barley by 2·10 bushels, beans by 5·13 bushels (the lowest since 1895), and peas by 0·54 bushel. On the other hand oats exceeded the average by 0·11 bushel per acre, potatoes by 0·54 ton, turnips and swedes by 1·57 tons, mangolds by 0·46 ton, hay (permanent pasture) by 1·03 cwt., and hay (clover, etc.) by 0·98 cwt.

In order to show the unfavourable character of the sowing period during the autumn, winter, and spring, it may be stated that the total area planted with wheat was the smallest during the 36 years covered by the official records; while that for barley was also the smallest on record. To the same cause may also be attributed the large area under bare fallow, which was the greatest since 1895.

Taking the British Isles as a whole, the corn harvest began 2 days later than the average date for the previous 15 years.

The yield of fruit was unusually good. The crop of apples proved a bountiful one in all parts of the country, while those of raspberries, currants, gooseberries, and strawberries were also good, particularly strawberries. On the other hand the crops of pears and plums were below average.

The Year.

The weather of the Phenological year ending with November 1904 was chiefly remarkable for the persistent rains in January and February, the absence of keen frosts in May, the long continuance of hot and dry weather in July, and the small rainfall during the autumn. Throughout the year wild plants came into flower behind their usual dates, but at no period were the departures from the average exceptional. Such spring migrants as the swallow, cuckoo, and nightingale made their appearance in this country at, as nearly as possible, their usual time. The yield of wheat per acre was the smallest since 1895, while those of barley, beans, and peas were also deficient. On the other hand there were good crops of oats and mangolds. The best farm crops of the year were, however,

TABLE II.—List of the Stations with the Names of the Observers.

Station.	County.	Height above Sea-level.	Observer.
A		Ft.	
1. Mawnan	Cornwall	200	Miss R. Barclay.
2. Altarnon	Cornwall	600	C. U. Tripp, M.A., F.R.Met.Soc.
3. Brixham	Devon	40	F. W. Millett.
4. Paignton	Devon	70	Miss M. Waite.
5. Starcross	Devon	50	P. G. Waterfield.
6. Tiverton	Devon	270	Miss M. E. Gill.
7. Barnstaple	Devon	90	T. Wainwright.
8. Sidcot	Somerset	200	W. F. Miller.
9. Clifton	Gloucester	300	G. C. Griffiths, F.E.S.
10. Penarth	Glamorgan	120	G. A. Birkenhead.
11. Bridgend	Glamorgan	90	H. J. Randall, Junr.
12. Castleton	Monmouth	80	Miss A. B. Evans.
13. Little Mill	Monmouth	300	W. J. Grant, F.R.H.S.
14. St. Arvans	Monmouth	360	Miss M. Peake.
15. St. Davids	Pembroke	220	W. P. Propert, LL.D., F.R.Met.Soc.
16. Aberystwith	Cardigan	30	J. H. Salter, D.Sc.
B			
17. Killarney	Kerry	100	Ven. Archdeacon Wynne, D.D.
18. Ferns	Wexford	260	G. E. J. Greene, M.A., D.Sc., F.L.S.
19. Bagenalstown	Carlow	290	Miss F. S. Wynne.
20. Ovoca	Wicklow	110	Miss W. F. Wynne.
21. Geashill	King's County	280	Rev. Canon Russell.
C			
22. Bembridge	Isle of Wight	80	C. Orchard, F.R.H.S.
23. Buckhorn Weston	Dorset	290	Miss H. K. H. D'Aeth.
24. Havant	Hants	30	H. Beeston.
25. Botley	Hants	30	Lady Jenkyns.
26. Fordingbridge	Hants	90	S. Bramley.
27. Birdham	Sussex	10	A. J. Nixon.
28. Muntham	Sussex	250	P. S. Godman, F.Z.S.
29. Dover	Kent	150	F. D. Campbell.
30. Staplehurst	Kent	110	Rev. J. S. Chamberlain.
31. Maidstone	Kent	100	Mrs. Silcock.
32. Chiddingfold	Surrey	230	Admiral Maclear, F.R.Met.Soc.
33. Cranleigh	Surrey	180	Miss H. E. Ravenscroft.
34. Coneyhurst	Surrey	600	J. Russell.
35. Churt Vicarage	Surrey	350	Rev. A. W. Watson.
35. Churt	Surrey	300	C. Criddle.
36. Oxshott	Surrey	210	W. H. Dines, F.R.Met.Soc.
37. Bagshot	Surrey	230	W. Burgess.
38. Weston Green	Surrey	30	H. T. Potter.
39. Marlborough	Wilts	480	E. Meyrick.
D			
40. Oxford	Oxford	200	F. A. Bellamy.
41. Beckford	Gloucester	120	F. Slade, F.R.Met.Soc.
42. Harefield	Middlesex	340	G. E. Eland.
43. Chesham	Bucks	300	Miss G. Keating.
44. Watford (The Platts)	Herts	240	Mrs. G. E. Bishop.
44. Watford (Weetwood)	Herts	270	Mrs. J. Hopkinson.
45. St. Albans (Worley Road)	Herts	300	H. Lewis.
45. St. Albans (New Farm)	Herts	400	Miss A. Dickinson.

TABLE II.—LIST OF THE STATIONS WITH THE NAMES OF OBSERVERS—*continued.*

STATION.	COUNTY.	Height above Sea-level.	OBSERVER.
		Ft.	
46. Berkhamsted	Herts	400	Mrs. E. Mawley.
47. Harpenden	Herts	370	J. J. Willis.
48. Ross	Hereford	210	H. Southall, F.R.Met.Soc.
49. Leominster	Hereford	220	J. H. Arkwright.
50. Farnborough	Warwick	520	Miss D. J. G. Prater.
51. Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.
52. Thurcaston	Leicester	250	The late Rev. T. A. Preston, F.R.Met.Soc.
53. Beeston	Notts	210	G. Fellows.
54. Hodsock	Notts	60	Miss Mellish, F.R.H.S.
55. Macclesfield	Cheshire	500	J. Dale.
56. Belton	Lincoln	200	Miss F. H. Woolward.
57. Sheffield (Endcliffe Rise Road)	Yorks (W.R.)	450	The late Miss E. F. Smith.
57. Sheffield (Ashgate Road)	Yorks (W.R.)	600	Miss Heatley.
58. Altofts	Yorks (W.R.)	120	H. G. Townsend.
59. Horbury	Yorks (W.R.)	210	W. Rushforth.
60. Ripley	Yorks (W.R.)	240	Rev. W. T. Travis.
E			
61. Broxbourne	Herts	120	Rev. H. P. Waller.
62. Hatfield	Herts	380	Miss R. Blackett.
62. Symons Hyde	Herts	300	T. Brown.
63. Hertford	Herts	140	W. Graveson.
64. Sawbridgeworth	Herts	350	H. S. Rivers.
65. Hitchin	Herts	220	A. W. Dawson, M.A.
66. Odsey (Ashwell)	Cambridge	260	H. G. Fordham.
67. Bocking	Essex	240	H. S. Tabor, F.R.Met.Soc.
68. Lexden	Essex	90	S. F. Hurnard.
69. Sproughton	Suffolk	30	The late Rev. A. Foster Melliar.
70. Roxton	Beds	...	Miss G. Day.
71. Carleton-Forehoe	Norfolk	100	Rev. C. H. Master.
72. Tacolneston	Norfolk	190	Miss E. J. Barrow.
73. Brundall	Norfolk	70	A. W. Preston, F.R.Met.Soc.
74. Southacre	Norfolk	100	Rev. E. T. Daubeney.
75. Brunstead	Norfolk	30	Rev. M. C. H. Bird.
76. Hevingham	Norfolk	...	Major Marsham.
77. Clenchwarton	Norfolk	10	Miss E. M. Stevenson.
78. Peterborough	Northampton	30	J. W. Bodger.
F			
79. Palé	Merioneth	600	T. Ruddy.
80. Betley	Stafford	250	Miss M. L. Hodgson.
81. Birkdale (Southp't)	Lancashire	40	E. J. Sopp, F.R.Met.Soc.
82. Lake Side	Lancashire	210	Miss L. Burton.
83. Ambleside	Westmoreland	260	Miss L. Armitt.
84. Cronkbourne	Isle of Man	110	A. W. Moore and J. Murphy.
85. Orry's Dale	Isle of Man	70	Miss A. M. Crellin.
G			
86. Ardgillan	Dublin	210	J. Woodward.
87. Edgeworthstown	Longford	270	J. M. Wilson, M.A.
88. Westport	Mayo	10	J. M. McBride.
89. Chanter Hill	Fermanagh	250	The Dean of Clogher.
90. Loughbrickland	Down	350	Rev. Canon Lett.
91. Saintfield	Down	310	Rev. C. H. Waddell, M.A.
92. Antrim	Antrim	70	Rev. W. S. Smith.

TABLE II.—List of the Stations with the Names of Observers—*continued.*

Station	County.	Height above Sea-level.	Observer.
		Ft.	
93. Altnafoyle	Londonderry	450	T. Gibson.
94. Milford	Donegal	150	Miss Osborne.
H			
95. Kirkmaiden	Wigtown	100	Rev. D. R. Williamson.
96. New Galloway	Kirkcudbright	450	T. R. Bruce.
97. Jardington	Dumfries	100	J. Rutherford.
98. Moniaive	Dumfries	350	J. Corrie.
99. Port Ellen	Isle of Islay	10	T. F. Gilmour.
100. Duror	Argyll	20	R. Macgregor.
I			
101. Doddington	Lincoln	90	Rev. R. E. Cole.
102. Thirsk	Yorks (N.R.)	120	A. B. Hall.
103. Durham	Durham	350	Prof. R. A. Sampson and F. C. H. Carpenter.
104. Corbridge-on-Tyne	Northumberland	200	A. W. Price.
105. Blyth	Northumberland	20	S. Dunnett.
J			
106. Kirriemuir	Forfar	250	T. M. Nicoll.
107. Durris	Kincardine	420	A. Macdonald, M.A.
108. Aberdeen	Aberdeen	40	P. Harper.
109. Fordyce	Banff	80	J. Ingram.
K			
110. Invermoidart	Inverness	60	S. M. Macvicar.
111. Roshven	Inverness	40	H. Blackburn.
112. Beauly	Inverness	60	A. Birnie.
113. Dingwall	Ross	10	J. P. Smith, M.D.
114. Inverbroom	Ross	50	Lady Fowler.
115. Watten	Caithness	150	Rev. D. Lillie.

The numbers before the names of the stations refer to their position on the Map of the Stations. Plate 2.

those of hay, turnips, and potatoes. Both corn and hay were harvested in excellent condition. Apples were everywhere abundant, and all the small fruits yielded well, especially strawberries, but there was a deficient supply of pears and plums.

Observers' Notes.

December 1903.—*Mawnan* (A)—1st. Dahlias killed. *Bembridge* (C)—2nd. Dahlias killed. *Buckhorn Weston* (C)—1st. Oats are now being reaped. *Churt Vicarage* (C)—25th. Flowers in bloom in Vicarage garden—rose, chrysanthemum, myrtle, double wallflower, snowdrop, etc. *Bagshot* (C)—12th. The oak leaves have all fallen. *Clenchwarton* (E)—Very few holly berries. *Thirsk* (I)—26th. Gathered over 100 fully open flowers of wild primrose on the west slopes of the Hambleton Hills.

January 1904.—*Mawnan* (A)—16th. Picked first bunch of snowdrops. *Tiverton* (A)—1st. Primroses gathered in a wood. *Ovoca* (B)—3rd. Rooks

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1904.

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
A													
Mawnan	42	...	...	92	...	130	139	159	168	199	...	217	268
Altarnon	70	69	106	116	115	128	152	165	170	201	214	213	270
Brixham	55	79	...	84	...	118	134	146	163	...	...	182	267
Paignton	52	49	76	101	115	124	138	143	149	156	...	192	...
Starcross	36	54	...	80	104	120	127	137	150	...	...	...	258
Tiverton	54	58	55	99	109	129	128	152	155	162	...	...	281
Barnstaple	31	55	106	103	104	120	131	149	158	172	202	193	270
Sidcot	39	53	...	...	...	...	...	...	...	...	...	...	...
Clifton	46	...	...	109	...	125	135	...	...	...	...	...	...
Bridgend	41	68	84	106	112	134	144	150	164	173	203	189	262
Castleton	37	72	77	101	113	115	135	146	155	167	...	...	...
Little Mill	41	46	83	99	117	132	135	137	158	173	...	175	249
St. Arvans	30	70	...	103	111	127	140	...	162	...	...	203	250
St. Davids	...	*93*	...	108	...	*142*	125	150	...	167	...	194	...
Aberystwith	42	...	104	94	104	...	136	...	157	167	193	188	255
B													
Killarney	21	81	69	78	...	104	131	146	160	199	190	195	249
Ferns	49	72	108	101	...	126	133	151	162	182	191	194	272
Bagenalstown	...	73	...	109	124	...	...	...	...	...	...	198	278
Ovoca	8	...	78	95	...	125	144	147	...	191	...	...	...
Geashill	53	53	83	105	...	134	148	148	...	...	...	...	264
C													
Bembridge	39	39	...	87	107	118	126	*129*	145	...	...	...	...
Buckhorn Weston	28	68	88	107	99	128	134	142	152	168	...	184	273
Havant	20	84	78	88	107	137	137	141	156	167	...	203	269
Botley	35	83	86	107	115	135	135	146	161	171	...	200	292
Fordingbridge	56	...	94	*131*	...	137	142	144	...	...	...	...	...
Birdham	35	75	...	102	117	121	122	151	158	177	...	...	283
Muntham	44	72	69	106	106	133	134	142	158	182	...	190	286
Dover	...	...	...	99	...	...	144	...	*174*	...	...	...	274
Staplehurst	32	68	76	101	102	119	127	145	153	...	...	202	...
Maidstone	32	42	79	107	107	120	133	140	156	171	189	191	268
Chiddingfold	32	52	80	106	116	122	140	146	157	175	197	206	273
Cranleigh	34	...	...	106	113	127	135	146	158	...	...	...	272
Coneyhurst	44	87	91	108	135	133	142	154	159	174	172	190	275
Churt Vicarage	32	...	99	112	116	130	139	144	162	173	181	209	...
Churt	30	*94*	92	109	...	128	133	...	*139*	172	...	199	*234*
Oxshott	51	...	96	108	...	...	130	...	...	...	...	...	...
Bagshot	29	...	96	...	...	127	138	135	158	173	...	204	272
Weston Green	36	75	94	107	119	123	135	149	...	...	206	219	272
Marlborough	28	68	54	105	109	131	139	151	158	185	194	182	...
D													
Oxford	...	...	...	...	...	...	...	149	...	...	...	...	268
Beckford	43	61	83	103	108	124	131	137	151	173	194	170	272
Harefield	59	*94*	94	109	116	127	138	143	...	...	...	...	*325*
Chesham	...	84	...	107	122	132	139	140	151	201	...	189	260
Watford (The Platts)	49	...	...	107	114	145	144	...	...	...	...	214	...

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1904—*continued.*

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
Watford (Weetwood)	46	76	101	102	110	122	138	139	155	186	...	...	263
St. Albans (New Farm)	...	...	...	...	130	...	...	...	151	...	179	195	278
Berkhamsted	45	68	92	110	112	127	146	148	151	197	196	191	280
Harpenden	41	76	103	112	116	127	133	153	156	...	...	...	295
Ross	30	58	93	89	106	121	123	143	155	170	...	185	276
Leominster	39	...	89	109	...	134	131	...	153	...	...	173	273
Farnborough	44	81	99	111	107	137	134	142	159	191	...	181	262
Northampton	44	74	74	107	123	128	135	146	157	178	192	198	258
Thurcaston	54	68	92	108	112	134	135	150	158	168	193	201	...
Beeston	54	79	...	114	126	135	...	163	169	180	162	...	...
Hodsock	49	71	89	103	119	122	137	156	164	179	191	184	276
Macclesfield	46	80	111	114	139	145	148	155	162	181	183	196	276
Belton	47	70	89	106	124	127	130	155	157	174	188	191	...
Sheffield (E. R. Rd.)	63	73	84	...	...	141	146	159	...	201	...	208	...
Altofts	59	49	96	115	122	143	146	159	167	187	199	200	275
Horbury	38	70	87	...	...	...	136	158	...	...	...	213	...
Ripley	41	87	92	114	129	137	148	...	...	...	...	...	...
E													
Broxbourne	36	75	80	...	108	...	...	...	158	...	...	...	260
Hatfield	...	...	...	...	...	...	...	...	160	...	199	...	...
Symonds Hyde	38	...	87	109	...	125	130	153	155	199	199	199	...
Hertford	24	45	84	108	108	119	129	143	150	192	...	203	262
Sawbridgeworth	32	...	95	100	115	137	141	...	...	...	...	...	...
Hitchin	49	71	92	105	109	123	127	...	152	...	198	...	...
Odsey (Ashwell)	...	...	...	...	...	...	...	...	153	...	...	...	266
Bocking	18	84	95	...	114	124	130	...	...	195	194	208	265
Lexden	35	70	90	105	117	123	132	144	156	170	...	189	264
Sproughton	...	...	...	105	110	121	132	141	157	...	...	...	...
Roxton	42	53	87	104	117	119	136	143	...	...	...	...	...
Carleton-Forehoe	38	77	...	112	119	127	140	149	157	180	197	...	...
Tacolneston	32	68	96	108	114	115	129	...	162	...	...	189	...
Brundall	52	*99*	93	107	113	131	133	143	162	...	...	...	275
Southacre	...	63	81	107	117	133	133	154	158	...	174	192	258
Brunstead	42	79	101	107	115	134	140	152	162	192	198	201	263
Hevingham	...	...	87	...	...	...	136	...	...	...	...	...	...
Clenchwarton	...	60	...	104	...	135	137	139	...	...	...	...	267
Peterborough	43	71	84	108	112	127	118	152	155	186	190	193	243
F													
Palé	48	64	107	107	130	142	149	153	163	199	196	216	292
Betley	47	80	84	101	133	133	136	161	170	184	197	194	273
Birkdale (Southp'rt)	...	72	...	116	133	141	145	160	...	191	197	201	280
Lake Side	30	83	94	115	...	130	149	158	163	199	196	192	271
Ambleside	29	...	...	111	...	...	...	159	173	208	193	...	268
Cronkbourne	53	81	116	...	136	138	147	158	...	198	...	215	286
Orry's Dale	...	...	...	...	...	...	...	150	161	...	199	...	...
G													
Ardgillan	*84*	72	89	107	...	132	148	149	172	218	...	...	287

TABLE III.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1904—*continued*.

STATION.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge-Mustard.	Horse-Chestnut.	Hawthorn.	White Ox-Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bind-weed.	Ivy.
Edgeworthstown	...	...	118	111	...	149	153	...	161	...	...	...	...
Westport	30	...	100	104	...	112	...	...	153	...	...	...	273
Chanter Hill	61	73	85	105	121	137	147	156	163	176	193	212	288
Loughbrickland	55	80	99	118	...	136	150	*172*	170	206	*219*	225	284
Saintfield	...	71	...	110	...	134	146	156	165	208	...	...	284
Antrim	60	76	97	110	...	...	147	157	158	200	...	204	...
Altnafoyle	71	74	94	114	...	147	151	...	171	211	...	...	...
Milford	61	71	...	104	...	120	147	156	162	183	...	220	...
H													
Kirkmaiden	...	49	...	121	...	149	154	...	179	...	...	198	...
New Galloway	24	86	113	123	...	151	...	165	167	206	200	...	...
Jardington	42	71	98	114	...	145	147	...	162	207	197	...	...
Moniaive	76	80	107	131	...	150	157	159	171	205	199	...	296
Port Ellen	76	...	99	115	...	153	148	...	161	...	193	195	269
Duror	51	66	81	117	...	...	143	164	162	186	188	...	282
I													
Doddington	53	*90*	95	114	126	127	140	159	161	...	...	...	258
Thirsk	34	62	92	109	118	140	140	150	161	...	...	...	...
Durham	...	...	...	...	...	...	150	175	176	...	...	...	...
Corbridge-on-Tyne	...	80	...	116	...	141	146	160	170	188	198	...	...
Blyth	49	51	96	116	129	148	146	162	168	192	196	206	...
J													
Kirriemuir	...	80	...	121	...	...	...	...	169	205	191	...	...
Durris	52	87	92	99	*148*	150	158	160	165	180	196	210	309
Aberdeen	...	78	119	...	...	151	154	167	172	...	...	...	...
Fordyce	68	71	107	111	125	143	149	...	171	199	202	212	286
K													
Invermoidart	...	...	106	...	...	...	152	178	182	213	...	...	269
Roshven	46	...	109	...	...	143	145	167	162	208	...	210	303
Beauly	32	94	118	127	...	156	154	166	162	197	200	...	295
Dingwall	46	...	107	117	...	145	154	161	163	...	...	...	...
Inverbroom	29	*35*	113	113	138	151	153	...	162	...	193	...	...
Watten	...	79	...	...	...	...	162	188	...	218	...	...	...

The dates in *italics* have not been taken into consideration when calculating the means given in Table IV.

building their nests. *Berkhamsted* (D)—17th. The last rose of the season was destroyed by frost—the latest date I have yet recorded (1885-1904). *Ripley* (D)—23rd. Great tit heard. *Thirsk* (I)—23rd. Daphne mezereum in flower. *Blyth* (I)—A field of beans was carted during the month by a farmer in the district.

TABLE IV.—MEAN DATES (DAY OF YEAR) FOR THE FIRST FLOWERING OF 13 PLANTS IN 1904, AND THEIR VARIATIONS FROM THE 14 YEARS' AVERAGE, 1891-1904.

Plants.	A England, S.W.			B Ireland, S.			C England, S.			D England, Mid.		
	1904.	Average for 14 Years.	Variation from Average.	1904.	Average for 14 Years.	Variation from Average.	1904.	Average for 14 Years.	Variation from Average.	1904.	Average for 14 Years.	Variation from Average.
Hazel	44	39	+ 5	33	32	+ 1	35	35	0	47	43	+ 4
Coltsfoot	61	56	+ 5	70	55	+15	68	62	+ 6	72	65	+ 7
Wood Anemone	86	86	0	85	75	+10	85	84	+ 1	92	89	+ 3
Blackthorn	100	92	+ 8	98	81	+17	104	97	+ 7	108	100	+ 8
Garlic Hedge-Mustard	110	107	+ 3	124	109	+15	112	111	+ 1	119	114	+ 5
Horse-Chestnut	125	121	+ 4	122	120	+ 2	128	127	+ 1	132	131	+ 1
Hawthorn	136	130	+ 6	139	128	+11	135	132	+ 3	138	134	+ 4
White Ox-Eye	149	146	+ 3	148	143	+ 5	145	142	+ 3	150	148	+ 2
Dog Rose	159	155	+ 4	161	156	+ 5	157	158	− 1	157	160	− 3
Black Knapweed	174	174	0	191	181	+10	174	171	+ 3	183	178	+ 5
Harebell	203	193	+10	191	*186*	+ 5	190	184	+ 6	188	190	− 2
Greater Bindweed	195	185	+10	196	190	+ 6	198	188	+10	193	192	+ 1
Ivy	263	264	− 1	266	254	+12	276	270	+ 6	272	271	+ 1
Mean for the 13 Plants	139	134	+ 5	140	132	+ 8	139	135	+ 4	142	140	+ 2

Plants.	E England, E.			F England, N.W.			G Ireland, N.			H Scotland, W.		
Hazel	37	36	+ 1	41	44	− 3	56	52	+ 4	54	50	+ 4
Coltsfoot	68	61	+ 7	76	66	+10	74	71	+ 3	70	75	− 5
Wood Anemone	89	87	+ 2	100	94	+ 6	97	87	+10	100	100	0
Blackthorn	106	98	+ 8	110	105	+ 5	109	101	+ 8	120	112	+ 8
Garlic Hedge-Mustard	113	111	+ 2	133	125	+ 8	121	*119*	+ 2	...	*122*	...
Horse-Chestnut	126	126	0	137	131	+ 6	133	131	+ 2	150	140	+10
Hawthorn	133	131	+ 2	145	138	+ 7	149	138	+11	150	143	+ 7
White Ox-Eye	147	146	+ 1	157	153	+ 4	155	155	0	163	159	+ 4
Dog Rose	157	157	0	166	161	+ 5	164	165	− 1	167	165	+ 2
Black Knapweed	188	179	+ 9	197	188	+ 9	200	200	0	201	199	+ 2
Harebell	194	188	+ 6	196	187	+ 9	193	*194*	− 1	195	190	+ 5
Greater Bindweed	197	192	+ 5	204	193	+11	215	201	+14	197	*198*	− 1
Ivy	262	264	− 2	278	282	− 4	283	276	+ 7	282	*277*	+ 5
Mean for the 13 Plants	140	137	+ 3	149	144	+ 5	150	145	+ 5	154*	151*	+ 3*

Plants.	I England, N.E.			J Scotland, E.			K Scotland, N.			British Isles.		
Hazel	45	50	− 5	60	*55*	+ 5	38	*53*	−15	45	44	+ 1
Coltsfoot	64	68	− 4	79	*77*	+ 2	87	*75*	+12	72	66	+ 6
Wood Anemone	94	95	− 1	106	*101*	+ 5	111	*99*	+12	95	91	+ 4
Blackthorn	114	109	+ 5	110	*112*	− 2	119	*110*	+ 9	109	102	+ 7
Garlic Hedge-Mustard	124	121	+ 3	125	*127*	− 2	138	*125*	+13	122	117	+ 5
Horse-Chestnut	139	140	− 1	148	*142*	+ 6	149	*140*	+ 9	135	132	+ 3
Hawthorn	144	142	+ 2	154	*146*	+ 8	153	*144*	+ 9	143	137	+ 6
White Ox-Eye	161	161	0	164	*160*	+ 4	172	*158*	+14	156	152	+ 4
Dog Rose	167	169	− 2	169	*172*	− 3	166	*170*	− 4	163	163	0
Black Knapweed	190	197	− 7	195	*189*	+ 6	209	*187*	+22	191	186	+ 5
Harebell	197	190	+ 7	196	*202*	− 6	197	*200*	− 3	195	191	+ 4
Greater Bindweed	206	197	+ 9	211	*203*	+ 8	210	*201*	+ 9	202	195	+ 7
Ivy	258	282	−24	298	*282*	+16	289	*280*	+ 9	275	273	+ 2
Mean for the 13 Plants	146	148	− 2	155	*151*	+ 4	157	*149*	+ 8	146	142	+ 4

* For 12 Plants.

\+ indicates the number of days later than the average date.
− ,, ,, ,, earlier ,, ,,
Av. ,, average date (1891-1904).
The dates in *italics* are approximate averages.

FEBRUARY.—*Altarnon* (A)—24th. First rook's nest completed. *Starcross* (A)—6th. Frog spawn first seen. *St. Arvans* (A)—7th. Chaffinch first heard. *Coneyhurst* (C)—Hazel bloom very abundant this year. *Belton* (D)—26th. Rooks beginning to build. *Odsey* (E)—25th. Rooks began building. *Tacolneston* (E)—Catkins on hazel very abundant. *Edgeworthstown* (G)—15th. Chaffinch first heard. *New Galloway* (H)—12th. Chaffinch first heard.

MARCH.—*Mawnan* (A)—19th. Peach in blossom. *Falmouth* (A)—The growth of vegetation generally retarded by the wet weather of the past six months. *Bridgend* (A)—2nd. Rooks on their nests. *Bembridge* (C)—10th. Nest of young thrushes seen. *Harpenden* (D)—8th. Rooks building. 9th. First swarm of bees. *Ripley* (D)—Chaffinch first heard on 8th, pied wagtail on 18th, and grey wagtail on 24th. *Birkdale* (F)—All insects remarkably late in their appearance. *Thirsk* (I)—6th. Rooks building. 21st. Blackbird's nest with eggs. *Fordyce* (J)—11th. Frog spawn first seen.

APRIL.—*Paignton* (A)—The blackthorn was so late in flowering that in many cases the leaves were out before the flowers. *Bridgend* (A)—3rd. Wheat-ear first seen. 6th. Martins first seen. *Ovoca* (B)—16th. Blackcap first heard. *Coneyhurst* (C)—12th. Sand-martins first seen. *Churt Vicarage* (C)—11th. Wryneck first heard. *Bagshot* (C)—30th. Grass plentiful in pastures. *Harefield* (D)—12th. Wryneck first heard. 19th. Martin first seen. *St. Albans* (*Worley Road*) (D)—14th. Wryneck first heard. 17th. Willow-wren first heard. 18th. Blackcap, white-throat, and tree-pipit first heard. *Berkhamsted* (D)—6th. An early River's peach in flower on a south wall, or 15 days later than its 18 years' average, and later than in any year since 1887. *Ripley* (D)—Sand-martin first seen on 5th, tit-lark on 6th, house-martin on 9th, and willow-warbler on 16th. *Tacolneston* (E)—20th. Wryneck first heard. *Southacre* (E)—13th. Sand-martin first seen. *Birkdale* (F)—26th. Frog spawn first seen. *Antrim* (G)—15th. Willow-wren first seen. *Jardington* (H)—20th. Sand-martin first seen. *Corbridge-on-Tyne* (I)—27th. Sand-martin and house-martin first seen.

MAY.—*Altarnon* (A)—18th. The cutting of peat and turf only now begun, owing to heavy rains of last autumn and winter. 31st. Scarcity of all butterflies, except the white ones. *Brixham* (A)—13th. Wheat-ear first seen. *Killarney* (B)—1st. Never a finer show of apple, pear, plum, and gooseberry blossom. 27th. Fruit blossom set well. *Geashill* (B)—Fruit tree blossom unusually fine, especially apples. *Botley* (C)—Apple blossom wonderfully fine and bright in colour. An exceptional number of slugs. 22nd. Oak leaves almost free from caterpillars. Orange-tip butterflies common. 30th. Scarcely any wasps. *Chiddingfold* (C)—15th. Tree foliage very full and free from damage by insects. *Churt Vicarage* (C)—4th. Bloom on laurels singularly abundant. 16th. May-fly first seen. 19th. First swarm of bees. 26th. Apple blossom exceptionally abundant. *Bagshot* (C)—16th. Apple trees in splendid bloom. *Harefield* (D)—16th. Night-jar first heard. *Watford* (*The Platts*) (D)—17th. Apple blossom very beautiful and abundant. *St. Albans* (*Worley Road*) (D)—1st. Sedge-warbler first heard. *Farnborough* (D)—Abundant blossom on plums, cherries, and apples. *Northampton* (D)—Fine show of blossom on the fruit trees. *Beeston* (D)—A wealth of blossom on apple trees. *Hodsock* (D)—The bloom on all flowering shrubs and fruit trees unusually abundant. *Macclesfield* (D)—31st. Many ash trees still almost devoid of foliage. *Ripley* (D)—Redstart first seen on 13th. *Bocking* (E)—Blossom very abundant on most trees, especially elms and ashes. *Southacre* (E)—1st. Blossom unusually profuse on blackthorn. This spring is remarkable for the abundance of blossom on the fruit trees. *Palé* (F)—Abundant blossom on apple and other trees. *Betley* (F)—Apple and pear trees crowded with blossom. *Lake Side* (F)—Blossom on fruit trees exceptionally abundant. *Orry's Dale* (F)—The spring and summer

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1904.

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A											
Mawnan	1	106	122	...	...	317	69	107	109	146	186
Altarnon	4	103	115	...	142	282	69	87	107	124	167
Brixham	4	122	123	...	...	281	*99*	102	111	*156*	183
Paignton	28	128	116	...	...	284	79	107	114	...	...
Starcross	8	105	106	...	...	285	38	130	108	108	...
Sidcot	8	97	105	...	...	...	69	...	112	132	...
Clifton	...	...	107	...	...	...	...	...	103	144	...
Penarth	...	...	...	...	...	...	78	107	106	...	180
Bridgend	6	99	122	...	...	273	68	125	108	136	157
Castleton	7	97	111	...	125	...	12	117	94	108	164
Little Mill	18	107	109	*132*	131	285	53	74	102	107	134
St. Arvans	12	104	105	...	135	279	67	133	105	149	...
St. Davids	...	88	118	...	...	...	86	...	94	140	...
Aberystwith	6	101	111	...	146	269	68	...	108	...	178
B											
Killarney	17	109	...	...	...	268	*106*	125	109	135	...
Ferns	2	96	115	...	...	270	53	128	114	127	136
Bagenalstown	3	106	116	...	...	...	40	110	110	112	...
Ovoca	1	102	118	...	...	280	70	70	109	114	...
Geashill	...	109	109	...	...	274	40	...	124	135	...
C											
Bembridge	7	95	103	102	...	304	53	...	107	150	179
Buckhorn Weston	1	100	105	114	147	289	68	115	102	116	168
Havant	12	93	104	105	142	311	68	72	103	135	189
Botley	12	105	97	107	143	288	54	107	97	134	170
Fordingbridge	8	96	105	105	136	...	45	...	...	145	...
Birdham	17	100	106	...	...	325	35	101	121	143	185
Muntham	28	102	105	108	136	296	48	...	115	126	...
Dover	...	103	...	...	...	...	...	...	...	...	...
Staplehurst	10	...	106	108	*107*	...	...	102	68	139	...
Maidstone	17	113	111	111	135	261	69	135	116	...	...
Chiddingfold	2	103	102	102	135	286	42	*154*	122	135	190
Cranleigh	12	113	102	104	...	286	...	...	104	117	...
Coneyhurst	*40*	106	104	110	131	277	68	110	124	...	..
Churt Vicarage	11	102	106	109	140	285	53	110	102	137	178
Churt	8	102	105	105	133	298	34	115	108	130	167
Oxshott	30	103	106	...	...	...	...	...	...	...	...
Bagshot	8	120	107	*121*	134	278	54	105	105	141	174
Weston Green	6	114	107	110	...	292	68	121	104	...	...
Marlborough	9	94	110	...	136	...	...	...	100	136	178
D											
Beckford	7	109	106	108	140	276	68	136	103	136	174
Harefield	...	116	106	107	...	290	...	...	116	...	...
Chesham	17	106	106	112	...	275	52	*169*	102	138	...
Watford (The Platts)	20	*133*	107	110	136	*229*	...	135	...	...	...
Watford (Weetwood)	...	107	104	108	...	278	67	115	105	...	...
St. Albans (Worley Road)	...	103	107	108	...	...	...	...	...	...	...
St. Albans (New Farm)	...	*121*	103	108	...	283	...	...	102	136	179
Berkhamsted	5	104	108	107	...	278	68	108	104	150	...

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 904—*continued.*

	Song.	Migration.					Insects.				
STATION.	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
Harpenden	8	103	106	104	...	...	...	109	105	...	*107*
Ross	5	106	113	113	*155*	276	...	...	...	...	...
Leominster	...	102	106	119	136	...	65	139	137	...	...
Farnborough	6	104	104	*148*	126	282	68	118	103	141	157
Beeston	...	120	117	...	124	277	71	124	115	...	...
Hodsock	14	104	117	106	136	294	18	129	133	140	...
Macclesfield	13	*148*	*139*	...	...	280	68	103	136	...	...
Belton	8	102	111	112	137	...	36	109	123	137	172
Sheffield (E. R. R.)	...	...	122	...	...	...	79	...	147	...	...
Sheffield (A. R.)	17	121	121	...	131	275	...	...	...	...	...
Altofts	24	103	112	...	...	295	...	...	116	...	*220*
Ripley	18	105	108	...	144	289	70	125	140	156	...
E											
Broxbourne	5	94	104	107	*163*	314	40	122	141	...	...
Hatfield	...	105	106	113	...	...	...	...	70	134	...
Symons Hyde	14	93	107	107	143	...	...	...	...	...	...
Sawbridgeworth	8	100	107	109	129	282	68	...	109	134	...
Hitchin	5	..	106	104	...	...	...	...	...	...	...
Odsey (Ashwell)	...	103	117	117	138	281	...	...	...	...	...
Bocking	...	...	114	112	...	...	...	...	...	...	...
Lexden	...	108	105	105	154	278	68	107	105	137	...
Sproughton	11	103	106	104	132	...	52	97	108	125	...
Roxton	...	107	106	...	141	...	52	110	110	...	136
Carleton-Forehoe	7	106	106	119	135	295	38	110	108	127	151
Tacolneston	6	106	...	108	...	305	36	116	...	139	...
Brundall	...	...	115	...	...	...	...	...	...	...	...
Southacre	...	104	114	116	129	287	...	94	120	135	176
Brunstead	4	111	105	...	148	280	33	105	114	141	193
Hevingham	*40*	*133*	118	...	...	...	...	...	...	...	...
Clenchwarton	...	109	117	...	...	283	68	117	107	138	...
Peterborough	4	107	108	108	...	255	68	65	...	135	...
F											
Palé	23	98	113	...	134	268	71	131	149	149	188
Betley	27	108	114	...	*160*	284	69	114	121	131	194
Birkdale (Southport)	...	*130*	125	...	142	281	85	...	127	135	175
Lake Side	...	114	120	...	...	...	87	132	136	132	...
Ambleside	45	104	119	...	...	274	...	...	141	...	198
Cronkbourne	13	107	136	...	...	271	38	120	116	118	...
Orry's Dale	7	...	...	...	...	...	38	*173*	...	...	...
G											
Ardgillan	19	108	120	...	137	257	...	110	105	130	175
Edgeworthstown	...	105	...	...	153	282	*107*	116	123	132	...
Westport	19	120	*150*	...	...	286	...	...	...	...	...
Chanter Hill	41	103	119	...	...	276	69	140	127	133	137
Loughbrickland	41	105	121	...	...	277	79	134	135	152	...
Saintfield	5	109	128	...	140	273	...	...	128	155	...
Antrim	19	106	124	...	143	280	95	155	121	141	...
Altnafoyle	...	126	130	...	...	...	*136*	*195*	132	140	200
Milford	23	111	120	...	...	273	70	...	131	132	160

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1904—*continued.*

Station.	Song.	Migration.					Insects.				
	Song-Thrush first heard.	Swallow first seen.	Cuckoo first heard.	Nightingale first heard.	Flycatcher first seen.	Swallow last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
H											
Kirkmaiden	20	99	126	...	...	...	88	...	131	...	...
New Galloway	45	120	118	...	...	268	53	124	149	...	...
Jardington	29	121	120	...	137	...	...	...	125	...	200
Moniaive	22	103	121	...	...	274	...	...	137	...	...
Port Ellen	20	106	122	...	...	...	22	...	...	...	...
Duror	50	105	119	...	143	282	61	109	152	...	...
I											
Thirsk	19	107	114	...	...	...	70	...	...	...	...
Durham	35	124	126	...	*107*	...	87	126	144	155	...
Corbridge-on-Tyne	29	115	126	...	...	282	...	...	...	...	...
Blyth	33	119	121	...	...	...	69	...	...	...	...
J											
Kirriemuir	...	120	131	...	...	265	69	...	...	...	...
Durris	24	116	115	...	148	263	58	114	124	...	199
Aberdeen	4	121	...	...	...	253	*108*	...	...	...	...
Fordyce	...	109	110	...	...	271	80	131	...	...	...
K											
Invermoidart	52	...	123	...	...	...	...	124	...	...	...
Roshven	21	123	123	...	...	...	...	154	150	...	...
Beauly	*80*	138	125	...	...	269	76	158	137	...	...
Dingwall	22	119	129	...	161	...	71	143	...	...	...
Inverbroom	27	138	123	...	...	...	59	155	145	...	...
Watten	...	...	*157*	...	...	...	83	...	143	...	...
Mean Dates for the British Isles in 1904	16 Jan. 16th	108 Apl. 17th	113 Apl. 22d	109 Apl. 18th	138 May 17th	281 Oct. 7th	60 Feb. 29th	117 Apl. 26th	117 Apl. 26th	135 May 14th	174 June 22d
Mean Dates for 1891-1904	Jan. 25th	Apl. 17th	Apl. 22d	Apl. 21st	May 14th	Oct. 12th	Feb. 25th	Apl. 12th	Apl. 18th	May 9th	June 11th

The dates in *italics* have not been taken into consideration when calculating the means for the British Isles.

were remarkable for the amount of blossom on all flowering shrubs. *Westport* (G)—Martin first seen on the 2nd, and sand-martin on the 19th. *Saintfield* (G)—The common field slug very abundant and destructive in gardens. *Antrim* (G)—Slugs very numerous and destructive. Apple and hawthorn blossom very abundant. *Altnafoyle* (G)—Willow-wren first heard on the 11th. *Jardington* (H)—Very few queen wasps. *Fordyce* (J)—8th. Scarcely a leaf to be seen on apple and plum trees owing to abundant blossom.

TABLE VI.—Estimated Yield of Farm Crops in 1904.

Description of Crop.	England.						Scotland.			Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H W.	J E.	K N.	B and G S. and N.	
	%	%	%	%	%	%	%	%	%	%	%
Wheat	+ 1	- 12	- 16	- 27	0	- 3	0	+ 3	- 26	+ 4	- 15
Barley	+ 5	- 2	- 10	- 16	- 2	0	- 3	- 1	- 12	- 18	- 8
Oats	+ 5	+ 1	- 6	- 8	+ 2	+ 3	0	- 1	- 8	+ 3	+ 1
Corn Harvest began, average Date, day of Year	222	214	219	218	230	233	243	244	243	241	231
Beans	+ 3	+ 3	- 30	- 30	+ 4	- 21	+ 10	+ 3	- 33	+ 2	- 22
Peas	+ 9	+ 4	- 5	- 5	+ 3	- 4	+ 4	+ 2	- 30	- 1	- 2
Potatoes	- 6	+ 1	+ 5	- 2	- 2	+ 9	+ 14	+ 21	+ 16	+ 10	+ 11
Turnips	+ 10	+ 15	+ 1	- 2	+ 9	+ 15	+ 11	+ 19	- 6	+ 15	+ 12
Mangolds	+ 12	+ 7	- 1	- 8	+ 5	- 5	+ 3	+ 5	- 8	- 7	+ 2
Hay (Permanent Pastures)	+ 10	+ 14	+ 1	- 2	+ 4	+ 5	+ 6	- 3	- 15	+ 5	+ 5
Hay (Clover, etc.)	+ 5	+ 14	+ 4	- 4	+ 7	+ 4	+ 5	+ 7	- 35	+ 5	+ 3

Symbols :— + = Over. – = Under. o = Average.

The variations from the average in the above-mentioned crops have been obtained from the *Agricultural Returns*, 1904 (*Produce of Crops*), issued by the Board of Agriculture, while the average dates of the Harvest have been derived from returns which appeared in the *Agricultural Gazette*, July 17 to September 10, 1904.

TABLE VII.—Estimated Yield of Fruit Crops in 1904.

Description of Crop.	England.						Scotland.	Ireland.	British Isles.
	A S.W.	C S.	D Mid.	E E.	F N.W.	I N.E.	H, J, and K W. E. and N.	B and G S. and N.	
Apples	+	+	+	+	+	+	+	+	+
Pears	–	–	–	o	–	–	–	–	–
Plums	–	–	–	–	–	–	–	o	–
Raspberries	+	+	+	+	+	+	+	+	+
Currants	+	+	+	+	+	+	+	+	+
Gooseberries	+	+	+	+	+	+	+	+	+
Strawberries	+	+	+	+	+	+	+	+	+

Symbols :— + = Over. – = Under. o. = Average. This Table has been compiled from returns which appeared in the *Gardeners' Chronicle*, July 30, 1904.

TABLE VIII.—VARIATIONS FROM THE AVERAGE IN MEAN TEMPERATURE, RAINFALL, AND SUNSHINE, 1903-4.

WINTER 1903-4.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
December . .	-1.6°	-2.2°	-1.6°	-1.6°	-1.2°	-2.4°	-1.6°	-1.8°	-1.4°	-2.2°	-1.8°
January . .	+1.5	+1.0	+1.0	+1.8	+0.5	+1.5	+0.8	+2.3	+1.5	+1.8	+1.8
February . .	-0.8	-2.0	+0.3	-1.0	+0.5	-1.5	-2.3	-1.3	-1.0	-2.3	-1.0
Winter . .	-0.3	-1.1	-0.1	-0.3	-0.1	-0.8	-1.0	-0.3	-0.3	-0.9	-0.3

Rain.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
December .	0.0	-0.5	-0.3	-1.3	-1.0	-1.1	-0.4	-1.8	-0.5	-1.1	-3.4
January . .	+0.9	+0.5	+1.3	+0.2	+0.1	+0.8	+1.1	+0.3	-0.3	0.0	+0.5
February . .	+2.8	+1.7	+1.6	+1.8	+1.0	+1.3	+1.1	+0.3	+0.9	+0.5	-0.3
Winter . .	+3.7	+1.7	+2.6	+0.7	+0.1	+1.0	+1.8	-1.2	+0.1	-0.6	-3.2

Sunshine.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December .	-12	-9	-26	-17	-25	-8	-9	-10	-28	-28	+4
January . .	-9	-15	-8	-9	-2	-4	-19	-11	-6	-11	-10
February . .	-29	-25	-9	-25	-25	-30	-28	-32	-29	-34	-16
Winter . .	-50	-49	-43	-51	-52	-42	-56	-53	-63	-73	-22

SPRING 1904.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
March . .	-2.4°	-1.8°	-2.2°	-2.0°	-1.8°	-2.8°	-2.0°	-2.2°	-1.4°	-1.8°	-0.6°
April . .	+1.0	+0.5	+1.5	+2.0	+2.3	+1.0	0.0	+1.3	+2.8	+1.0	+0.5
May . .	-0.8	-1.0	+0.3	-0.3	+1.5	-0.8	-1.0	-1.3	+1.0	-1.0	-1.3
Spring . .	-0.7	-0.8	-0.1	-0.1	+0.7	-0.9	-1.0	-0.7	+0.8	-0.6	-0.5

Rain.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
March . .	-0.7	+0.6	-0.4	-0.3	-0.2	0.0	+0.1	+0.5	-0.5	-0.2	-0.9
April . .	-0.4	-0.7	-0.6	-0.5	-0.7	+0.1	+0.3	+1.5	-0.6	+0.2	+3.8
May . .	+0.9	+0.1	+0.6	0.0	-0.1	-0.2	-0.2	+0.7	+0.5	+0.7	+1.2
Spring . .	-0.2	0.0	-0.4	-0.8	-1.0	-0.1	+0.2	+2.7	-0.6	+0.7	+4.1

Sunshine.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March . .	-31	-29	-27	-23	-30	-15	-10	-26	-40	-9	+2
April . .	-5	-16	+1	+11	+7	+17	-10	+4	+24	+9	-19
May . .	-63	-27	-44	-40	-47	-29	-18	-43	-34	-29	-15
Spring . .	-99	-72	-70	-52	-70	-27	-38	-65	-50	-29	-32

+ indicates above the average, - below it.

TABLE VIII.—VARIATIONS FROM THE AVERAGE—*continued*.

SUMMER 1904.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
June . .	−0·8	+0·2	−1·0	−1·2	−0·2	−0·8	0·0	0·0	−0·6	−0·4	+0·8
July . .	+2·5	+1·0	+2·5	+3·0	+3·0	+1·8	+1·0	+1·3	+2·0	0·0	+0·5
August . .	−0·2	−0·4	0·0	−0·4	+0·6	−0·6	−0·8	−0·2	+0·6	0·0	+0·2
Summer . .	+0·5	+0·3	+0·5	+0·5	+1·1	+0·1	+0·1	+0·4	+0·7	−0·1	+0·5

Rain.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
June . .	−0·8	−0·3	−0·8	−1·4	−1·0	−0·7	−0·4	−0·5	−0·8	−0·6	+0·2
July . .	+1·2	+0·5	−0·5	+0·4	+0·1	−1·2	+0·4	−0·6	−0·4	−1·4	−1·7
August . .	−0·5	+0·1	−0·1	+0·1	−0·4	+0·4	+2·0	+0·7	+0·3	+0·9	+1·2
Summer . .	−0·1	+0·3	−1·4	−0·9	−1·3	−1·5	+2·0	−0·4	−0·9	−1·1	−0·3

Sunshine.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June . .	+16	+16	+18	+20	−2	+44	+16	+34	−3	+17	+48
July . .	−1	+20	+47	+29	+52	+31	+18	−17	−2	−28	+21
August . .	+28	+14	+36	+42	+41	+44	+9	+12	+26	+1	+17
Summer . .	+43	+50	+101	+91	+91	+119	+43	+29	+21	−10	+86

AUTUMN 1904.

Temperature.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
September .	−0·5	−0·3	−2·0	−1·3	−0·8	−0·5	0·0	+0·8	+0·3	0·0	+1·3
October . .	+1·5	+2·3	+1·0	+1·0	+1·5	+0·8	+1·3	+1·8	+1·3	+1·5	+1·3
November .	−0·8	0·0	−1·0	−1·2	−0·6	−0·4	+1·0	−0·2	0·0	0·0	−0·4
Autumn . .	+0·1	+0·7	−0·7	−0·5	0·0	0·0	+0·8	+0·8	+0·5	+0·5	+0·7

Rain.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
September .	−1·1	+0·3	−1·2	−1·0	−1·0	−1·7	−0·7	−0·7	−1·0	−1·2	−0·2
October . .	−1·4	−1·2	−0·8	−2·1	−1·4	−1·8	−1·0	−1·5	−2·0	−1·8	−0·6
November .	−1·6	−2·2	−1·7	−1·0	−1·2	−0·9	−0·1	−2·1	−0·9	−1·8	−0·5
Autumn . .	−4·1	−3·1	−3·7	−4·1	−3·6	−4·4	−1·8	−4·3	−3·9	−4·8	−1·3

Sunshine.

MONTHS.	Eng. S.W.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. N.W.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September .	+25	+6	+29	+39	+40	+43	+37	+38	+34	+20	+31
October . .	−15	+58	−12	−1	+6	+22	−9	−3	+13	+22	−4
November .	−5	−27	+8	−5	−4	+4	−19	+3	+6	+13	+3
Autumn . .	+5	+37	+25	+33	+42	+69	+9	+38	+53	+55	+30

The above Table has been compiled from the variations from the mean given in the *Weekly Weather Reports* issued by the Meteorological Office.

TABLE IX.—SUPPLEMENTARY OBSERVATIONS IN 1904.

PLANTS.

WINTER ACONITE.

Station.	District.	Date.
Bembridge . .	C	Jan. 16.
Churt Vicarage .	C	„ 15.
Bagshot . .	C	Feb. 20.
Berkhamsted .	D	Jan. 13.
Ripley . .	D	Dec. 25.
Clenchwarton . .	E	Jan. 1.
Cronkbourne .	F	„ 9.
New Galloway .	H	„ 17.

BIRDS.

CHIFF-CHAFF (first heard).

Station.	District.	Date.
Altarnon . .	A	April 16.
Starcross . .	A	March 29.
Ovoca . . .	B	April 2.
St. Albans (Worley Road)	D	„ 10.
Ardgillan . .	G	„ 23.
Loughbrickland .	G	„ 17.

CORNCRAKE (first heard).

Station.	District.	Date.
Bridgend . .	A	May 4.
Ovoca . . .	B	„ 3.
Leominster . .	D	„ 29.
Ripley . .	D	„ 8.
Lake Side . .	F	„ 19.
Ardgillan . .	G	April 24.
Westport . .	G	April 17.
Antrim . .	G	„ 24.
Saintfield . .	G	„ 23.
Altnafoyle . .	G	May 6.
Moniaive . .	H	„ 4.
Corbridge-on-Tyne	I	„ 5.
Durris . . .	J	„ 9.
Fordyce . .	J	„ 7.
Inverbroom . .	K	„ 12.
Watten . .	K	„ 20.

SWIFT (first seen).

Station.	District.	Date.
Mawnan . .	A	May 14.
Brixham . .	A	„ 12.
Bridgend . .	A	„ 3.
St. Arvans . .	A	„ 13.
Cranleigh . .	C	„ 14.
Churt Vicarage .	C	„ 12.
Harefield . .	D	„ 15.
St. Albans (Worley Road)	D	„ 11.
Leominster . .	D	„ 12.
Ripley . .	D	„ 9.
Odsey . . .	E	„ 13.
Lake Side . .	F	„ 14.
Westport . .	G	„ 18.
Antrim . .	G	„ 3.
Altnafoyle . .	G	„ 19.
New Galloway .	H	„ 16.
Corbridge-on-Tyne	I	„ 22.
Fordyce . .	J	„ 1.

JUNE.—*Mawnan* (A)—10th. First hay cut. *Penarth* (A)—Buttercups singularly abundant. *Bridgend* (A)—20th. Hay first cut. *St. Arvans* (A)—10th. Hay first cut. *Ovoca* (B)—Few butterflies except whites and orange-tips. An unusual amount of blossom on the flowering shrubs. *Bembridge* (C)—9th. The cold damp weather has brought the potato disease—the earliest date I have ever recorded. The bee and other native orchids very strong and fine this year. *Botley* (C)—The cold and wet up to the 18th made the strawberry-growers very anxious; suddenly the weather changed and the strawberries ripened at once. 34,000 gallon baskets were sent away in one day. At last it did not pay to pick the fruit. This was the most prolific season for strawberries ever known *Maidstone* (C)—3rd. Haymaking began. *Bagshot* (C)—16th. Haymaking began. *Harpenden* (D)—21st. First wheat-ear out of sheath, later than in either of the previous 12 years. Foliage of gooseberries greatly infested with caterpillars. The July drought checked growth of wheat and caused it to be the worst crop since 1879. *Farnborough* (D)—Small white butterflies very numerous *Hodsock* (D)—30th. Grass very brown. *Macclesfield* (D)—Blossom of all kinds abundant. *Tacolneston* (E)—13th. A blackbird having reared her brood in some fagots in a wood-shed, has laid and

hatched a second family in the same nest. *Palé* (F)—Hawthorn especially full of blossom. *Betley* (F)—18th. Cuckoo last heard. 20th. Hay cut. 24th. Hay carted. *Lake Side* (F)—Quite a plague of caterpillars, acres of underwood with all the leaves destroyed by them. *Cronkbourne* (F)—16th. Hay harvest began. *New Galloway* (H)—29th. Cuckoo last heard. *Jardington* (H)—Hawthorn and apple blossom abundant. *Moniaive* (H)—Apple, pear, and cherry trees laden with blossom. 27th. Hay harvest began. *Thirsk* (I)—Very few cuckoos this year, a rare occurrence. 7th. House-martin's nest built ready for eggs. 12th. First hay cut. 15th. Roses almost free from aphis *Fordyce* (J)—16th. The gale did much damage to flowers and fruit. The trees the next day as if blighted by a severe frost. *Watten* (K)—16th. The gale did much damage to fruit trees.

July.—*Altarnon* (A)—Heavy crops of peat turf and early hay were mostly gathered in by July 20th. 31st. Early potatoes badly diseased. Wireworms, slugs, and snails unusually destructive both on farm and in garden. *Maidstone* (C)—16th. Oats cut. *Churt Vicarage* (C)—26th. All my lawns are quite brown. *Bagshot* (C)—25th. Corn harvest began. *St. Albans* (*New Farm*) (D)—Winter oats cut and burnt on the fields owing to ravages committed by wireworm. *Beeston* (D)—8th. Pastures and lawns quite brown. 21st. A large number of small apples falling off. 26th. A very grateful rain, which in two days caused a marvellous change in the appearance of the pastures. *Hodsock* (D)—Everything suffering from effects of the dry weather before the rain came on the 23rd. *Brunstead* (E)—13th-16th. Dense swarms of aphis. Outside tomatoes and broad beans smothered with them. 15th. Black currants dropped from the bushes owing to drought. *Clenchwarton* (E)—White butterflies very numerous. In some fields the beans were so injured by aphis as to be of no value. *Birkdale* (*Southport*) (F)—Large numbers of aphis on willows, sycamore, etc. 7th. Cuckoo last heard. *New Galloway* (H)—29th. Swift last seen. *Fordyce* (J)—There has been a good yield of honey. *Beauly* (K)—Towards the end of the month the pastures were burnt up on light soils.

August.—*Mawnan* (A)—1st. Corn harvest began. *Churt Vicarage* (C)—Wasps not so numerous this year as usual. 25th. Vegetable marrows injured by frost in the lower part of the parish. *Bagshot* (C)—Wasps fairly numerous. 20th. First appearance of potato disease. *St. Albans* (*New Farm*) (D)—Blackberries good and plentiful. *Beeston* (D)—22nd. A quantity of mushrooms. *Hodsock* (D)—1st. Harvest began. 31st. Harvest finished. *Odsey* (E)—1st. Began cutting wheat. 29th. Harvest completed. *Tacolneston* (E)—The drought in July and August has been very severe. Much injury has been done in the garden by aphis. *Clenchwarton* (E)—Wasps numerous. 1st. Corn harvest began. *Palé* (F)—No wasps to be seen all the month. *Betley* (F)—26th. Last swift seen. *Birkdale* (*Southport*) (F)—26th. Have seen but one wasp. *Cronkbourne* (F)—Very few wasps. 8th. Corn harvest began. *Antrim* (G)—12th. Swift last seen. *Moniaive* (H)—29th. Corn harvest began. *Fordyce* (J)—20th. Swift last seen.

September.—*Mawnan* (A)—26th. Holly-berries have now turned scarlet. *Altarnon* (A)—30th. Very few mushrooms this year. *Churt Vicarage* (C)—15th. Red admiral butterflies scarce. *Bagshot* (C)—2nd. Harvest completed. Potatoes not much diseased. 28th. Poor yield of honey. Have only seen two mushrooms. *Farnborough* (D)—About half the usual quantity of honey. *Hodsock* (D)—9th. From this time the garden was very gay with flowers. *Odsey* (E)—25th. Fly-catcher last seen. *Southacre* (E)—Great quantities of mushrooms in August and September. *Clenchwarton* (E)—22nd. Autumn tints unusually fine. *Palé* (F)—Very few wasps or butterflies this month. *Birkdale* (*Southport*) (F)—But very few wasps.

October.—*Altarnon* (A)—Large crops of sloes, haws, hips, blackberries, mountain-ash berries, and other wild fruits. *Brixham* (A)—18th. Several

swifts seen. *Tiverton* (A)—11th. Wild strawberries gathered. *Penarth* (A)—Mountain-ash berries unusually abundant. *Churt Vicarage* (C)—10th. Very large crop of acorns. 15th. Dahlias killed by frost. *Bagshot* (C)—Enormous crop of acorns. 14th. Fine autumn tints. *Chesham* (D)—The martins left on the 21st. *Hodsock* (D)—13th. Dahlias killed by frost. *Macclesfield* (D)—The finest autumn tints I have ever seen. *Sawbridgeworth* (E)—20th. Small white butterfly last seen. *Carleton-Forehoe* (E)—A very large crop of acorns and blackberries this year. *Tacolneston* (E)—The autumn tints have been remarkably beautiful this year. 21st. Last house-martins seen. *Clenchwarton* (E)—A large number of berries, especially holly-berries. *Palé* (F)—The foliage of trees brilliantly coloured all through the month. *Moniaive* (H)—7th. Harvest completed.

NOVEMBER.—*Altarnon* (A)—12th. Wasps still abundant. 30th. Much injury done to the foliage of trees, rhododendrons, laurels, and bracken by the combined effects of snow, hail, and frost. *Brixham* (A)—Ripe wild strawberries till the end of the month. *Starcross* (A)—10th. The clouded yellow and red admiral butterflies last seen. *Tiverton* (A)—10th. Decorated a table with sweet-peas and roses from our garden. 21st. When the frost came there were 46 kinds of garden flowers out. *St. Arvans* (A)—6th. Wasps seen on ivy blossom. *Bagenalstown* (B)—On the 20th, the day before the cold spell, I counted 54 different flowers out in my garden. *Ovoca* (B)—13th. Gathered the last peas and French beans. 20th. Dahlias killed. *Geashill* (B)—Garden gay with flowers until frost of the 21st. *Bembridge* (C)—5th. Martins seen at Ventnor. *Churt Vicarage* (C)—12th. The autumn tints very fine this year. 17th. Gathered a bloom of Maréchal Niel rose on a south-east wall. *Beckford* (D)—Beautiful autumn weather until the 22nd, followed by a week of severe frosts. *St. Albans* (*New Farm*) (D)—22nd. Mangold roots frozen. *Berkhamsted* (D)—15th. Dahlias killed, 10 days later than the average for the previous 19 years. *Northampton* (D)—The last week of the month intensely cold. *Beeston* (D)—22nd. First snow. 24th. Thermometer in screen showed 22° of frost. *Hodsock* (D)—Autumn tints very bright. *Sawbridgeworth* (E)—5th. Bees and wasps seen. *Odsey* (E)—There were no flocks of wood-pigeons this autumn. In the winter of 1903-4 they were very large. *Lexden* (E)—Trees have ripened their wood well. *Tacolneston* (E)—2nd. First woodcock. 11th. First fieldfare. *Clenchwarton* (E)—19th. A good many roses still in flower. *Palé* (F)—Dahlias in flower until cut off by snow and frost on the 22nd. *Cronkbourne* (F)—21st. Dahlias killed. *Moniaive* (H)—17th. Scabious, cowslip, and mignonette still in flower in garden. *Durris* (J)—19th. Flowers still out on many wild plants such as broom, scabious, sneezewort, etc. A cottar family in this district have made, during the last six weeks, £10 by the sale of blackberries. *Fordyce* (J)—19th. Cold intense. Previously the weather had been remarkably warm. *Roshven* (K)—10th. Dahlias injured by frost. *Beauly* (K)—Weather fine and warm till the 20th, when snow set in.

DISCUSSION.

THE PRESIDENT (Mr. RICHARD BENTLEY) said that each year added a further link in the long chain of their indebtedness to Mr. Mawley for the laborious work he had undertaken in connection with English Phenology. Indeed, as much as sixteen years had already elapsed since he undertook, in succession to the Rev. T. A. Preston—the announcement of whose death they deplored this evening—the task of collating the observations of living nature with the physical ones taken artificially by means of instruments, and of translating in a very charming

manner into artistic pictures on the screen the results of our sometimes somewhat uninviting masses of pen-and-ink statistics. Phenology had a great advantage over most forms of scientific study, in that it required no expensive paraphernalia of instruments, and hence it became possible to add more readily to the roll of observers—and he was glad to learn that the list of those qualified for the purpose was growing. In the earlier days of phenology, observers were extremely few and far apart, and so much depended on the unceasing watchfulness and opportunity of a single person, that there was always some danger then of "a single swallow making a summer,"—in the absence of a sufficient number of observations from different parts of the country to give the average dates. Herr Gätke had noted over a long course of years the track of migrants visiting our shores, and it was observed in the flight of these birds across Europe that they kept every year to the same route, and that a narrow one—neither stretching to the north of it in favourable seasons, nor to the south in severe ones—and this uniformity appeared to confirm Mr. Mawley's remarks to-night as to the limits of deviation being very rigidly controlled. So much time and work were involved in the preparation of these annual reports, that he (Mr. Bentley) hardly liked to offer any suggestion that might add to these ; yet he thought it might be of general interest if Mr. Mawley should have the opportunity, on some future occasion, to give, briefly, a comparison of the methods employed in this country, and (allowing for climatic differences) those adopted on the Continent and in the United States, to acertain how far the objects selected for observation are in agreement, and how large is their margin of variation under different conditions. One other point he would like to mention, a problem which confronts every dweller in the country—the still unsolved mystery of the rise and fall of the sap, an event which should be an important feature in phenological observations, when some day perhaps another Harvey might arise to elucidate the mode of its circulation or movement.

Mr. J. E. Clark remarked that he was always exceedingly interested in the Phenological Report. He was much struck by the long series of cold springs that we had experienced. May had been referred to once or twice in this respect, but last year March had been the principal offender. Last March the number of plants in flower in his own garden at Croydon was only 21, as compared with 46 in the same month in 1893, which was a very forward season, the oak being in leaf on the first week in April. In April last year the number had increased to 52, and in May to 78, as compared with 49 (an addition of 3 only) and 59 in the previous year. At the other end of the year, at Christmas 1902, 23 wild plants were found in flower ; in 1903, 16 ; while last year only 11 were to be found.

Dr. W. N. Shaw said he had listened to Mr. Mawley's Report with much interest. He had been engaged recently in an attempt to summarise the meteorological data of the *Weekly Weather Report* in a form which would facilitate inquiry into the meteorological conditions of observed phenological results, the yield of crops and other similar questions. One aspect of the inquiry, the relation between autumn rainfall and the yield of wheat, had already been noticed in the public press. It had found an explanation of the deficient yield of 1904 after the favourable spring and summer of that year in the excessive rainfall of the autumn of 1903. There were many other subjects of investigation suggested by the Report. Would not some Fellow of the Society take up the question of the regularity with which the dog-rose made its appearance, and find out what peculiar combination of meteorological events led to that regularity ? Or again, to what extent did the phenological results of the forest trees or deeper-rooted plants differ from those of the shrubs and herbs ? Great stress had been laid on air-temperature as causing phenological differences. It would be interesting to know how far the results showed that temperature

was the primary consideration, and how far its effects might be modified by other elements.

Mr. H. MELLISH said that gardeners had been most prophetic that 1904 would be a very bad year for fruit owing to the extreme wetness of the previous autumn, and to the impossibility of the new growth on the plants hardening sufficiently before the flowering season came round. This, however, was completely falsified, and 1904 would long be remembered for the extraordinary profusion of blossom and fruit of every kind. Could Mr. Mawley trace any relationship in the matter? Mr. Mawley had mentioned in the Report that swedes and turnips had done very well; but that was certainly not the case in his own immediate neighbourhood in Nottinghamshire, where they were the worst product of the year. The young plants did not come up well and had to be re-sown; and, notwithstanding the heavy rains in August and the fine weather of September, did not do at all well. He was sorry Mr. Mawley's Report did not have a wider circulation, and he thought if it could be distributed amongst the Natural History Societies it would be greatly appreciated.

Capt. D. WILSON-BARKER remarked that Mr. Mawley's figures were gradually becoming an invaluable storehouse of information. He was inclined to think with Dr. Shaw that temperature was a determining factor in the growth of animals and plants. In his own opinion the migration of birds was not governed by meteorological conditions. Their flight was impelled by an instinct, the cause of which was at present unknown; and frequently they were caught by adverse conditions and killed. This was not so much the case with insects, many of which hybernated through the winter, and were likely to come out any fine warm day. The cabbage butterfly, however, was different, it being formed in the chrysalis in the autumn, and required a certain amount of heat before it could emerge.

Mr. F. GASTER agreed with most of Mr. Mawley's conclusions, especially with regard to the shortness of plums. He thought that the temperature of the previous winter as well as the rainfall should be considered as affecting the crops. A heavy crop would not be gathered after very cold conditions, while abundant rain tended to rot the roots.

Mr. BALDWIN LATHAM said he could corroborate the Report of Mr. Mawley with reference to the production of fruit from what had taken place in his own garden at Croydon. He would suggest that the deficiency in the yield of the wheat crop in 1904 was due to the excessive wet period in the year 1903, during which year a large amount of percolation took place, which washed out the soluble manurial elements and left the soil impoverished. It was now understood that the food of plants was prepared in the soil by bacteria, and the food so prepared was in a very soluble condition and would be washed out of the soil in the presence of much water, leaving the soil poor and impoverished. All through the year 1903 rapid percolation was going on, so that there was no period of the year in which accumulations of manurial elements could be formed in the soil. In 1904, for over five months, from June to November inclusive, no percolation took place, which would result, if he was correct, in an accumulation of manurial elements in the ground, which will beneficially affect the wheat crop of 1905. In the present autumn and winter the percolation had been so very slight, 1·98 ins. had percolated in four months, October to January, while in the corresponding period in the year 1903-4, 12·65 ins. percolated. It was well known that the effect of drought on the growth and yield of wheat was nothing like so detrimental as excessive wet, and the effect of the diminution of percolation during last summer and autumn could not but have a beneficial effect in producing a good wheat harvest in the present year.

Mr. E. MAWLEY, in reply, said that it was only by confining his attention to the requirements of the Report itself that he could now hope to find time

for its preparation, otherwise he should have been pleased to carry out the excellent suggestion of the President as to the methods adopted by other countries. In respect to the effect of dry and wet autumns on the yield of wheat, he considered that Dr. Shaw's curves fully bore out all he claimed for them. They clearly showed the importance of obtaining a satisfactory seed-bed in the autumn for wheat, and how dependent the farmer was upon the weather at that season, for in a wet autumn to secure such a seed-bed in anything like heavy soil was of course impossible. He could only account in some measure for the great regularity in the flowering of the dog-rose by the fact that plants which came into blossom during the summer were, as a rule, more consistent in this respect than those flowering either earlier or later in the year. As regards the abundant blossom on the fruit and other trees after such a wet summer and autumn as that of 1903, he said that although the wet weather was very beneficial to all kinds of trees, the cold summer caused the new growths they made to be rather sturdy than long and sappy, so that these shoots may have become better ripened before the spring of 1904 than had been generally supposed. That the abundant water in the subsoil was appreciated by them, is shown by the well-nourished appearance of the trees, and the vigorous character of their blossoms. No doubt, as Mr. Latham had pointed out, the soil must have become a good deal impoverished by the constant and heavy rains in October and February. He, however, thought that the principal cause of the exceptionally small crop of wheat was due to the saturated condition of the ground at the sowing time. The weather of the present winter had been most favourable for the farmer, but owing to the scanty rainfall it must have had just the contrary effect upon the underground water-supply, which was likely to be very deficient this year.

Long-Range Weather Forecasts.

The U.S. Weather Bureau has published a paper on the subject of long-range forecasts by Prof. E. B. Garriott. From a review of the opinions of many of the leading meteorologists of the world regarding the application of past and present astronomical and meteorological knowledge to the theory and practice of long-range weather forecasting, the author arrives at the following conclusions :—

1. That systems of long-range weather forecasting that depend upon planetary meteorology ; moon phases, cycles, positions, or movements ; stellar influences, or star divinations ; indications afforded by observations of animals, birds, and plants ; and estimates based upon days, months, seasons, and years have no legitimate bases.

2. That meteorologists have made exhaustive examinations and comparisons, for the purpose of associating the weather with the various phases and positions of the moon, in an earnest endeavour to make advances in the science along the line of practical forecasting, and have found that while the moon, and perhaps the planets, exert some influence upon atmospheric tides, the influence is too slight and obscure to justify a consideration of lunar and planetary effects in the actual work of weather forecasting.

3. That the stars have no appreciable influence upon the weather.

4. That animals, birds, and plants show by their condition the character of past weather, and by their actions the influence of present weather and the character of weather changes that may occur within a few hours.

5. That the weather of days, months, seasons, and years affords no indications of future weather further than showing present abnormal conditions that the future may adjust.

6. That six- and seven-day weather periods are too ill-defined and irregular to be applicable to the actual work of forecasting.

7. That advances in the period and accuracy of weather forecasts depend upon a more exact study and understanding of atmospheric pressure over great areas, and a determination of the influences, probably solar, that are responsible for normal and abnormal distributions of atmospheric pressure over the earth's surface.

8. That meteorologists are not antagonistic to honest, well-directed efforts to solve the problem of long-range forecasting ; that, on the contrary, they encourage all work in this field and condemn only those who, for notoriety or profit, or through misdirected zeal and unwarranted assumptions, bring the science of meteorology into disrepute.

9. That meteorologists appreciate the importance to the world at large of advances in the period of forecasting, and are inclined to believe that the twentieth century will mark the beginning of another period in meteorological science.

Prof. Willis L. Moore, the Chief of the U.S. Weather Bureau, in the Introduction to Prof. Garriott's paper, says :

"The success of the United States Weather Bureau in making conservative forecasts of the weather two or three days in advance has created the hope in the minds of the people that it may be possible to foresee the character of the weather for the coming month or season. All scientific men know that at present it is impossible to gratify this wish, and the Government experts so inform all those who make inquiry. But the mistaken investigator of little knowledge, the pseudo-scientist and the astrologer, see their opportunity, and at once step into the breach, and sell spurious long-range forecasts to a public rendered credulous by the success of the Government scientists. The abuse of the public confidence has become so great that I have thought it justifiable to present to the reader indisputable evidence of the injurious character of monthly or seasonal forecasts.

"It is the opinion of the leading meteorologists of the world that public interests are injured by the publication of so-called long-range weather forecasts, especially by such predictions as relate to severe storms, floods, droughts, and other atmospheric disturbances of a dangerous or damaging character. The publication of monthly forecasts has reached such proportions that it is deemed advisable to inform the public as to their harmful character. Some monthly forecasters may be honest, and may, in their ignorance, attach undue importance to storms that accidentally coincide in time of occurrence with certain relative positions of the moon, or with periods of increase or decrease in sun-spots, or apparent variations in the solar intensity. To men of this class the occurrence of a storm within the broad area of the United States on or near the day for which they have predicted a storm confirms, in their minds, the value of their system of prediction. They may believe that they have discovered a physical law or a meteorological principle that has not been revealed to astronomers, meteorologists, or any other class of scientific investigators ; but the publication of predictions that, by reason of their inaccuracy, are positively injurious to agricultural, commercial, and other industrial interests, casts a doubt upon the honesty of their makers.

"As a result of my personal verification of the work of long-range weather forecasters, some of whom have so far gained the confidence of the rural press as to receive liberal compensation for their predictions, I am led to the conclusion that these forecasters do positive injury to the public at large. It is to be regretted that so many newspapers not only give space to these harmful predictions, but actually pay for them. Forecasts of this description may properly be classed with advertisements of quack medicines—they are both harmful in the extreme."

OBSERVATIONS OF METEOROLOGICAL ELEMENTS MADE DURING A BALLOON ASCENT AT BERLIN, SEPTEMBER 1, 1904.

By HERMANN ELIAS, Ph.D., and J. H. FIELD, B.A., B.Sc., F.R.Met.Soc.

[Read February 15, 1905.]

The ascent was made in the balloon *Brandenburg*, of 1250 cub. m. (44,100 cub. ft.) capacity, belonging to the Aeronautical Observatory of the Königl. Preuss. Meteorologisches Institut, and afforded — together with the readings of a "Ballon-sonde" sent up an hour previously—the September Berlin records of the simultaneous monthly International Ascents.

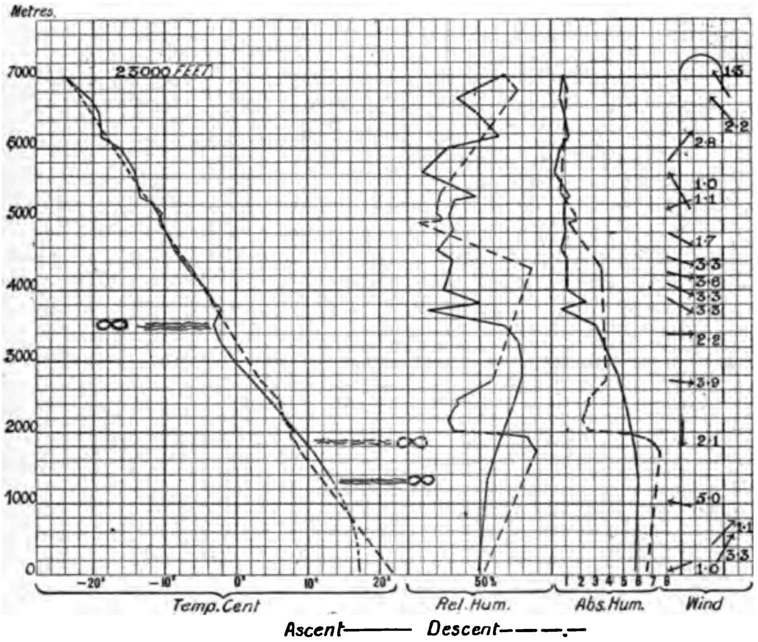


Fig. 1.

The observations taken included readings of Assmann's aspirated dry- and wet-bulb psychrometer, of radiation black-bulb thermometer with vacuum jacket, of mercury and aneroid barometers, and of time; while a recording aneroid and a vertical current anemometer gave evidence for the management of the balloon. The direction and velocity of the wind was exactly determined from time to time by tracing on a hand-map the path of the end of the overhanging trailing rope seen projected against the ground below.

A general reference to the table of figures, and to the altitude-temperature curve (Fig. 1), will show that on the ascent two main air-strata were encountered: the first from ground-level up to 3500 m.

(11,500 ft.),[1] with a prevalent wind direction due East, the second—separated from this by an inversion 200 m. (650 ft.) thick, giving a 3° C. (5°·4 F.) departure from an adiabatic curve—extending upwards to the maximum height reached, and showing a prevalent Westerly wind direction. On the descent three main strata were met with: from 7000 m. (23,000 ft.) to 5000 m. (16,400 ft.), from 5000 m. to 2000 m. (6600 ft.), and from 2000 m. to ground-level, the separations being effected in each case by small inversions of about 1°·5 C. (2°·7 F.). The general direction of wind during descent was from the South-east, but its velocity was very small till the balloon reached the South-south-west or surface wind at about 350 m. (1200 ft.) above the ground.

Starting at 8.13 a.m., the first temperature reading above the surface was taken at a height of 1327 m. (4350 ft.), and differed so little from that at the ground as to make it probable that the usual temperature inversion up to about 300 m., formed at night and corrected during early morning, had not had time to disappear. In the temperature diagram this part of the curve is shown dotted to indicate lack of information; it is quite possible that, in addition to the ground inversion, a smaller one also occurred at a height of 1300 m. (4300 ft.), marking the upper limit of an observed stratum of haze which had gradually increased in density up to that level. The balloon's velocity of ascent was at the time too great to allow closely consecutive observations to be taken.

At 9.7 a.m. the inversion at 3500 m. (11,500 ft.) was passed through, and presumably extended with the same or with decreasing altitude northwards, for till late in the day few clouds formed in that direction, the rising of the moisture-laden air being checked before it had reached the critical expansion for cloud-formation. The air above the inversion is shown by the curves of humidity to be comparatively dry, so that no higher-level heavy clouds were to be expected.

To the south and south-west, however, there had appeared at 8.59 a.m. on the horizon the first-formed cumuli of the day, which by 9.21 a.m. had become a bank of cumulo-stratus of considerable thickness, indicating—hygrometric conditions being taken to be about the same—that the inversion surface was kinked sharply upwards towards the south. This cumulo-stratus bank steadily approached, not moving appreciably as a whole, for there was little wind near it, and that in a contrary direction, but being continuously augmented on its sloping north-west front by the formation of new cloud.

This wave-front or kink in the temperature-inversion surface was advancing as a whole during the day, and at the same time slowly rising, allowing the formation of the new cloud and accounting for the higher levels of the inversions at 5000 m. (16,400 ft.) and 2000 m. (6600 ft.) recorded by the balloon during its descent, when it was within 10 to 15 km. (6 to 9 miles) of the cloud-bank, its geographical position having remained practically unchanged.

At 10.56 a.m., when the cumulo-stratus was distant about 30 km. (19 miles), the level of its top was observed to be 3800 m. (12,500 ft.) approximately, while at 2.5 p.m. it had risen to 5000 m. (16,400 ft.).

[1] Heights were calculated and estimated in metres, but the corresponding values in feet are given here in brackets. In cases of estimation, only roughly corresponding values are inserted.

This general rise would not of itself, however, account for the great thickness of 2800 m. (9200 ft.) of cloud which had by then formed up much closer to the balloon; it must have been aided by the actual advance of the kink in the surface of inversion.

At 12.30 p.m., when the balloon was near its maximum height, and well above the level of the top of the cloud-bank, the trend of the bounding surface was found to be north-north-west and east-south-east, with the considerable curvature indicated on the small-scale map in Fig. 2 (thick broken line); it will be seen that the boundary was approximately parallel with the low-pressure (760 mm.) (29·92 ins.) isobar for 7 a.m. that morning, plotted from observations afterwards received from the various Continental stations.

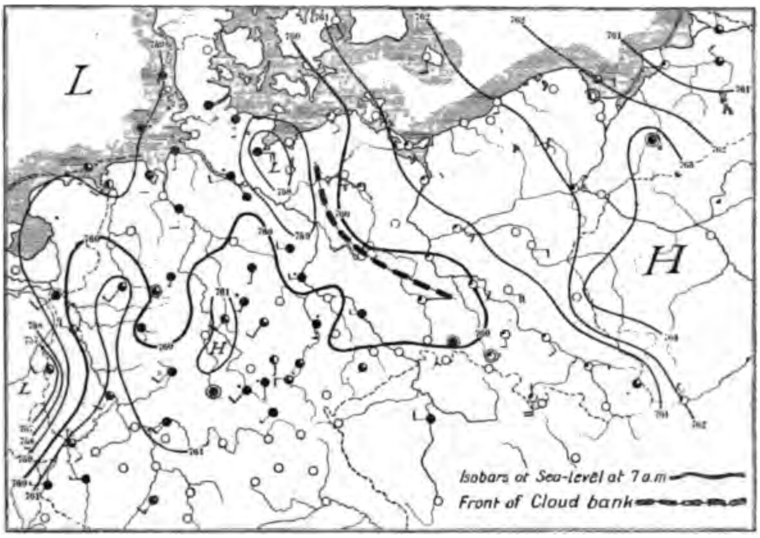


Fig. 2.—Weather Chart, September 1, 1904.

The top edge of the cloud-bank, at a level of approximately 3800 m. (12,500 ft.), was noted as early as 9.21 a.m. to be very flat, no longer having the tumbled appearance of rising convectional cumuli, but seeming to have reached a steady height and to be unable to rise freely farther. This appearance was, however, modified when the balloon had risen sufficiently to give a good view of the top of the bank; for, rising out of its flat surface, at a distance of perhaps 100 km. (62 miles) or more to the north-west, stood a projecting mass of cumulus of about 2000 m. (6600 ft.) extra height, of a diameter which was possibly 50 to 100 km. (31 to 62 miles), and whose summit formed the radiant point of a system of cirro-stratus clouds sweeping in curves upwards in all directions, and dying away overhead at a height estimated at 9000 m. (30,000 ft.) to 10,000 m. (33,000 ft.). A strong sun-shadow was thrown by the aggregated cirro-stratus strands on to the brightly illuminated upper surface of this cumulus extrusion, leaving no doubt that actual contact between the two cloud-formations occurred at the summit. Over this area, then, the temperature inversion had been interrupted, with the result that the

cumulo-stratus had risen above the surrounding surface and attained a total height of somewhere near 7000 m. (23,000 ft.), where, presumably after the discharge of rain had been rendered possible by the extra rise of 2000 m. (6600 ft.), it afforded by its residual moisture the frozen particles of the cirro-stratus filaments and strands which were carried upward still farther and radially dissipated by the strong cyclonic updraught of air. The subsequent Weather Reports showed that the area round Hamburg and Heligoland (see Fig. 2) displayed all the characters of cyclonic condition,—low pressure, mist, and rain,—and in addition a considerable distribution of dust-laden air, due to rapidly ascending currents, had been indicated by the fall of "dirty" rain. It seems probable that these appearances on the upper cloud surfaces were situated over or near Hamburg, and were directly concerned with the fall of rain experienced there. They may have extended in an unbroken length

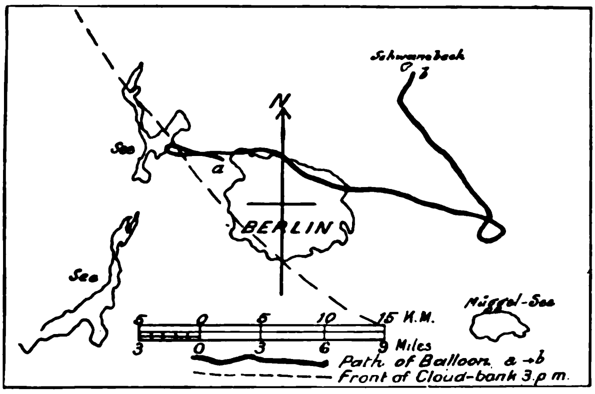


FIG. 3.—Path of Balloon.

over Heligoland also, or more probably a separate extrusion of cumuli through the inversion surface occurred there; the position of the balloon did not allow more than an end elevation of the phenomenon to be observed.

In the region in which the balloon lay, on the other hand, *i.e.* over the north of Berlin, and from there northwards, the conditions were anticyclonic; higher pressure, clear bright weather, and few clouds, with an uninterrupted view beyond the Oder to the north-east, and as far as the Baltic Sea to the north-north-east. Flecks of cumuli lay below the balloon, advancing as forerunners of the approaching cloud-bank, and with their bases level with its lower limit at 2300 m. (7550 ft.); they were ranked conspicuously in lines parallel with the boundary of the cumulo-stratus, with a constant distance apart. The whole system of cumulo-stratus was manifestly of dynamic formation, due to the strong indraught of air towards the cyclonic area in the lower stratum, together with the upper air-currents returning opposite to their previous paths after breaking through the cumulus head and carrying with them the radiating bands of cirro-stratus.

Some time after the ascent was begun, it was noted without immediate explanation that the balloon showed a strange reluctance to rise, and con-

siderable expenditure of ballast was necessary to overcome its sluggishness. This gave rise to the speculation that there were strong descending currents of air completing a circulation, the explanation of which would perhaps be given on the formation of clouds later in the day. The registering aneroid frequently indicated a slow fall of the balloon when the vertical current anemometer showed very little motion to bear this out. In the light of the further observations made later in the morning, it appeared to be correct that a steady downward current in the anticyclonic area was being encountered, which carried the balloon with it while showing but little lateral velocity. On reaching higher levels, the observed change in direction of the wind, giving a travel away from the cyclonic area, was in accordance with the circulation above indicated as likely to be occurring on the periphery of the low-pressure zone.

The strong bands of cumuli ranged in advance of the cloud-bank were of considerable interest, as indicating the approach of bad weather in waves, the hindmost of which formed the outskirts of the advancing solid cloud-bank behind. It was noteworthy that the forerunner of all these cumuli wave-crests—some 80 km. (50 miles) in front of the bank—was considerably stronger than those succeeding it, forming, indeed, a continuous roller of cloud across the field of view, and that a more or less constant decrease in volume of the crests behind it occurred until, when nearly below the balloon, and 15 km. (9 miles) from the cloud-bank, they died away in quasi-cirro-cumulus forming regular wave-crests of much smaller pitch and great tenuity, whose wave motion could be seen most beautifully from above by reason of its projection on the clearly visible ground beneath. The solution of the crests into clear vapour as they sank into the wave hollows, and their reappearance on again rising, was strikingly visible. It seems probable that the strong line of cumulus wave-crest forming the first advancing front occurred as the result of the first contact of the indrawn rising lower air with the outwardly advancing upper air, and that it marked the boundary beyond which the upper current slowly descended in the anticyclonic area, to become perhaps a part of the lower inflowing current which had acquired its first appreciable velocity there. As might be expected in that case, the subsequent cumuli wave-crests became less pronounced in character with the settling down of the two-current strata into their normal uninterrupted courses.

The difference of temperature between the protected aspirated thermometer and the black-bulb exposed instrument rose from 24 degrees centigrade (43 degrees Fahrenheit) near 3000 m. (9900 ft.) to 61 degrees centigrade (110 degrees Fahrenheit) near the maximum height reached, the increase being mostly due to a rise of the temperature of the radiation thermometer.

During the descent the conditions had changed with the closer proximity of the cloud-bank. The inversion surfaces had risen on their way towards the 5000 m. (16,400 ft.) level of the cloud-top, while the lower of them now bounded at a level of 2000 m. (6600 ft.) a dense haze of a blackish colour, probably composed of the same dust-particles which had formed a conspicuous feature of the "dirty" rain of Hamburg that day and the evening before.

Mr. H. H. Clayton, of Blue Hill Observatory, has pointed out in his memoir, *Studies of Cyclonic and Anticyclonic Phenomena with Kites*, that the

anticyclonic inversion surfaces are lens-shaped, convex upwards, his observations, consisting of detached periodic readings, extending at intervals of some hours over several days at a time. Although in this case only two soundings of the air, and those close in front of the cyclone, were obtained, so that no information as to the shape of the inversion surface through the anticyclone was afforded, yet it is clear that the surfaces of like condition changed continuously and rapidly, tending to a maximum height over the central rainy area of the cyclone.

In addition, it is to be noted that in this central area the inversion ceased, allowing the rise of a mass of cumulo-stratus to 7000 m. (23,000 ft.) and the subsequent formation of cirro-stratus up to 10,000 m. (33,000 ft.), —a condition of the cyclone that has not before, it is believed, been actually observed to hold. It seems clear, however, that either that must be so, or at any rate that a considerable elevation of the inversion surface must exist to account for the rain associated with the low-pressure wave; the former condition would alone afford the necessary outlet for the generally ascending cyclonic currents. This discontinuity does not appear to have been recorded by Clayton, probably because his point of observation did not lie in a diametral plane of the low-pressure minimum. No evidence was afforded by the cloud-bank of any descending current in the core of the cyclone, such as has been suggested in the Blue Hill memoir.

With regard to the general conduct of the balloon trip, it may be mentioned that a steel cylinder of 1000 litres of oxygen was carried for the use of the two observers when above the 5000 m. (16,400 ft.) level. Eighteen bags and two corner boxes of sifted sand, totalling about 500 kg. (1100 lbs.), were taken; five bags being retained for purposes of safe landing, as for a long time there seemed a likelihood of the descent taking place in or near Berlin itself. A tearing line for very rapidly emptying the balloon when approaching the ground obviated the necessity of carrying a grapnel.

The physiological effects of the rarity of air at 7000 m. (23,000 ft.) were interesting, one of the observers finding that a stoppage of oxygen-breathing for a minute or two caused a general greyness to overspread the whole view gradually, but without giving any feeling of sickness, while resumption of oxygen-inhalation caused an instantaneous renewal of the actual colours of the landscape, but with greatly enhanced vividness, which, however, very rapidly decreased to the normal hues. Difficulty, also, in reading the instruments, except after a few seconds' oxygen-breathing, was found at levels higher than 5000 m. (16,400 ft.).

Despite the low air-temperatures experienced, the heat in the sunshine made it superfluous to wear much extra clothing; but careful wrapping up in the shade of the car, and the use of thick felt overboots with foot-warmers in the toes, were necessary provisions against cold.

In general, although the possible information to be gathered from a balloon ascent is curtailed on every hand by the want of means to make continued observations in all the various air-strata for some time before and after the ascent, and to extend those observations over a considerable area, yet so far as the method goes it affords results which are more trustworthy than those obtained with kites. In addition, the actual presence of observers who will not be confined to the making of notes solely on the four elements temperature, pressure, humidity, and wind—as is a

TABLE EXTRACTED FROM LOG OF OBSERVATIONS.

International Balloon Ascent, September 1, 1904, Berlin.

Balloon *Brandenburg*, 1250 cub. m. (44,100 cub. ft.) capacity, filled to 1000 cub. m. (35,300 ft.) at 756·5 mm. (29·78 ins.). Start from Reinickendorf at 8.18 a.m. Weather very hazy; clouds 4° ci.-str., str.-cu., wind light ENE. at ground. Travel—53 km. (33 miles); total distance from starting-place, 17 km. (10·5 miles); average velocity, 2·2 m. p. s.; mean direction, N. 66° E. Total time, 6 hrs. 39 mins. Greatest height, 7044 m. (23,110 ft.). Lowest temperature, −24° C. (−11°·2 F.).

Time.	Pressure.		Height above Sea.		Temperature. Aspirated.		Temperature. Radiation.		Vapour Pressure.		Relative Humidity.	Humidity. Grams Water per kg. Air.	Sun.	Clouds and Remarks.
a.m.	mm.	ins.	metres.	ft.	° C.	° F.	° C.	° F.	mm.	in.	%			
7·55	756·5	29·78	40	131	17·1	62·8	...	...	7·06	·278	49	5·86	...	4° ci.-str., str.-cu., ∞².
8·13	Started Reinickendorf.													
8·25	650	25·59	1327	4,354	13·3	55·9	...	...	6·30	·248	55	6·00	...	4° ci., ci.-str., ∞ (over ∞).
8·37½	543·5	21·40	2803	9,196	1·4	34·5	25·6	78·1	4·03	·158	80	4·65	$\odot^2$	
8·44	531	20·91	2990	9,810	− 0·1	31·8	27·8	82·0	3·66	·144	80	4·31	$\odot^2$	4° ci., ci.-str.; dynamic cumuli on horizon; balloon full.
8·52	Vertically over starting-place again.													
8·59	513	20·20	3268	10,722	− 2·3	27·9	28·7	83·7	3·01	·118	77	3·67	$\odot^{1-2}$	First cumuli in south.
9·7	498·5	19·63	3496	11,470	− 3·2	26·2	27·0	80·6	2·48	·097	68	3·15	$\odot^{1-2}$	
9·10	497	19·57	3520	11,549	...	...	...	...	...	...	...	...	...	Come over a haze.
9·16	484·5	19·08	3722	12,211	− 2·1	28·2	29·7	85·5	0·54	·021	14	0·7		
9·21	479	18·86	3813	12,510	− 3·4	25·9	24·4	75·9	1·67	·065	46	2·17	$\odot^{1-2}$	Cumuli in S. cannot rise, and now become cu.-str.
9·37	468	18·43	3999	13,120	− 4·2	24·4	26·8	80·2	0·84	·033	25	1·12	$\odot^{1-2}$	Cumuli form under balloon.
9·44	454·5	17·89	4228	13,871	− 6·4	20·5	30·8	87·4	0·82	·032	29	1·13	$\odot^{1-2}$	Balloon unsteady; will not rise.
10·56	421	16·57	4833	15,856	− 10·0	14·0	26·5	79·7	0·70	·028	32	1·04	$\odot^2$	In S. cu.-str. bank about 1000 m. (3300 ft.) below [us.
11·14	410	16·14	5038	16,529	− 10·8	12·6	33·2	91·8	0·61	·024	29	0·92	$\odot^{1-2}$	3° ci.-str., 2¹ cu., ∞; cu.-str. bank approaches.
11·43	395·8	15·58	5312	17,428	...	...	...	...	...	...	...	...	$\odot^2$	2° ci.-str., 5^{1-2} cu.-str.
p.m.														
12·20	345	13·58	6354	20,847	...	...	...	...	...	...	...	...	...	Balloon is very disturbed and unsteady.
12·48	314·7	12·39	7037	23,088	− 24·0	− 11·2	37·0	98·6	0·45	·018	68	0·87		
1·58	393	15·47	5368	17,612	− 13·1	8·4	29·9	85·8	0·42	·016	24	0·67	...	Almost level with cu.-str. top.
2·5	411·5	16·20	5014	16,450	− 10·7	12·7	32·0	89·6	0·50	·020	24	0·76	...	Level with cu.-str. top.
2·6	414	16·30	4967	16,293	− 10·8	12·6	32·8	91·0	0·48	·019	23	0·72		
2·7	415	16·34	4948	16,234	− 10·8	12·6	...	...	0·16	·006	8	0·24		
2·17	451	17·72	4301	14,111	− 6·3	20·7	...	...	2·54	·100	87	3·51		
2·27 (?)	549	21·62	2732	8,963	+ 3·1	37·6	...	...	3·38	·133	59	3·84	...	Level with small cu. clouds.
2·29	568	22·36	2455	8,055	+ 5·9	42·6	...	...	2·35	·093	34	2·58	...	Over ∞.
2·32	598	23·54	2032	6,667	7·8	46·0	...	...	2·52	·099	32	2·64		
2·32½	602	23·70	1976	6,483	7·5	45·5	...	...	5·35	·211	69	5·54		
2·33½	611	24·06	1854	6,083	8·2	46·8	...	...	6·89	·271	85	7·11	...	In ∞.
2·52	Good landing near Schwanebeck.													
3·5	756·3	29·77	40	131	21·8	71·2	...	...	10·34	·407	53	6·63		

Note.—For permission to publish these figures acknowledgment is due to Prof. Dr. Richard Assmann of the Berlin Meteorological Observatory.

meteorograph—is always an advantage. In the present case, by far the most interesting features of the atmospheric conditions, characteristic of the meeting-point of the cyclone on the one quarter with the anticyclone on the other, would have been unappreciated if the only means of studying them had been a meteorograph chart.

DISCUSSION.

THE PRESIDENT (Mr. RICHARD BENTLEY) said that the authors of the paper referred to the advantage of these investigations if more observations could be made. He hoped himself that by the increasing development of mechanical power and the use of extremely light motors it would soon be possible to make balloon ascents even in calm or foggy weather.

Mr. C. HARDING thought that if a chart of the barometric conditions prevailing at the time had been coupled with the observations, it would have been of great advantage. If Mr. Glaisher's balloon observations had been discussed with synchronous weather charts, it would doubtless throw light on many of the temperature variations which seemed to need an explanation. He had looked up the daily maps for the period under discussion, and had found that Berlin was on a ridge between two areas of low pressure, which supported the observations of the descending currents referred to in the paper. He would recommend that any of the Fellows making balloon observations should also discuss the weather conditions taking place on the surface of the ground at the same time.

Atmospheric Pressure and the Nile Flood.

This subject has been dealt with by Capt. H. G. Lyons, the Director-General of the Survey Department of Egypt, in a paper read before the Royal Society on February 2. The following are the general results of his investigation :—

1. Generally speaking, the curve of Nile floods varies inversely as the mean barometric pressure of the summer months: high pressures accompany low floods, and low pressures accompany high floods.

2. These pressure variations show a great similarity over wide areas, from Beirut to Mauritius, and from Cairo to Hong-Kong, and are usually of Sir N. Lockyer's Indian type of curve or Prof. Bigelow's "direct" type.

3. Occasionally, however, pressure at Beirut and Cairo is in disagreement with that of the rest of the area, and then more nearly approaches the "Cordoba" type of Sir N. Lockyer, or the "indirect" type of Prof. Bigelow. This would seem to be a confirmation of other evidence which tends to show that Egypt belongs to the class of Brückner's "temporarily exceptional" areas.

4. Taking the monthly means of atmospheric pressure, this relation is even more clearly shown, and pressure above or below the normal, in months of the rainy season of Abyssinia, coincides closely with deficiency or excess of rainfall.

5. Taking the 35 years 1869 to 1903, in 6 years out of 7 a very fairly accurate prediction of the flood from month to month could have been made.

THE WINDS OF EAST LONDON, CAPE COLONY.

By J. R. SUTTON, M.A., F.R.Met.Soc.

[Read February 15, 1905.]

EARLY in the year 1904 the Harbour Board of East London, thanks to the kind services of Capt. L. A. Munn, placed some anemometer sheets at my disposal for discussion, and the present paper gives the results of a preliminary study of the same.

The anemometer is well placed on an erection surmounting a dwelling-house, at an altitude of about 150 feet above, and a distance of a few hundred yards from, the sea. It is of the ordinary Kew pattern, the vane being of the windmill type, with 9-inch cups for velocity. The instrument has been in use for more than twenty years, and it seems probable that some of the various bearings have worked a trifle loose. One consequence is that some little irregularity is introduced into the records between 10 and 11 a.m., just after the sheets are changed; another, that the traces of both direction and velocity are, in the later months, exceedingly faint. This defect is most noticeable in the velocity diagrams: the sheets containing them have to be inclined more or less to the light before they can be read at all; and, besides, the trace is so broad (for the spiral pencil has worn very flat) that high wind velocities are not easy to determine within 1 or 2 miles per hour.

The position of the anemometer is approximately 27° 55′ E., 33° 2′ S. The time system is for the meridian of 22° 30′ E., and is therefore 22 minutes later than local mean time.

The records discussed in this paper are nearly complete for the three years 1898, 1899, and 1900. There are some small gaps here and there, where records are missing or the clock has stopped, and two large ones, namely, July 19-22, 1898, and December 20, 1899 to January 6, 1900. This last has been partially filled by the inclusion of January 1-6, 1897, and December 26-31, 1897. Finally, after rejecting all hours in which the vacillation of the vane made any assignment of the direction worthless, we have left for discussion 25,759 hours of direction and velocity together, out of a three years' maximum of 26,280 hours—say 521 hours, equal to nearly 22 days, or about 2 per cent short. In computing the hourly, daily, and monthly velocities irrespective of direction, however, 25,923 hours of velocity have been taken into account. Each of these hours has been tabulated for direction and velocity to the sixteen principal compass points. We shall find it convenient to consider the directions alone at first.

In Table I. will be found the monthly number of hours of wind from assigned directions during the three years. It appears from this that North-east is the prevailing direction, South-west being next in order of magnitude, with West-south-west a close third. It is important, however, to notice a fundamental difference between the North-east and South-west winds: the former blow from a nearly definite small arc which shares little supremacy in its own quadrant with any other direction; the South-west winds, on the other hand, belong to a group of winds occupying more than a whole quadrant from South-south-west to

North-west. When this is taken into consideration, it is seen that for practically one-half the year the vane is pointing to some South-westerly direction. Winds from the North are not more frequent than about two hours in three days on an average. Winds from South-east and adjacent directions are even less frequent, the total duration of all wind springing from the South-east quadrant averaging scarcely an hour a day. It appears then that the prevailing winds blow up or down the coast, no great interchange existing between sea and land.

TABLE I.—Wind Frequency in Hours: Monthly Totals.

Month.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
January	31	179	477	142	39	41	27	20
February	37	220	505	108	25	35	19	38
March	22	221	558	106	36	37	9	21
April	54	318	270	83	27	13	15	32
May	94	208	233	44	11	10	10	12
June	98	158	131	63	19	11	7	12
July	128	212	178	23	7	14	4	3
August	128	253	279	47	23	22	18	31
September	66	177	280	74	36	49	21	27
October	37	177	367	111	56	35	32	35
November	32	126	407	209	67	44	35	35
December	21	129	396	133	46	95	65	79
3 Years	748	2378	4081	1143	392	406	262	345
Month.	**S.**	**SSW.**	**SW.**	**WSW.**	**W.**	**WNW.**	**NW.**	**NNW.**
January	47	263	406	318	87	77	18	41
February	36	202	292	239	125	75	14	35
March	45	88	377	282	196	150	28	36
April	35	153	266	297	205	216	79	61
May	27	159	207	305	258	294	180	176
June	28	113	164	239	254	360	280	189
July	24	128	139	208	240	274	345	176
August	47	190	206	241	234	210	168	120
September	50	266	375	329	159	124	50	41
October	75	312	324	267	211	96	40	27
November	85	253	284	251	147	80	25	47
December	74	299	259	221	126	81	18	36
3 Years	573	2426	3299	3197	2242	2037	1245	985

Tracing the prevalence of winds in the North-east quadrant through the year, we see that the vane tends to turn more to the North of the mean direction during the colder months, April to August, and more to the South between October and March. There is this further peculiarity, that while for three-fourths of the year the total duration of North-east quadrant winds varies little, in the Winter the falling off is considerable. The North-east winds are indeed three times more pronounced in the Summer than in the Winter.

Very nearly the same may be said of the winds in the South-west quadrant. The Northerly deviation of the vane in the Winter is even more decided, so that North-westerly winds, which are not on the whole of cardinal importance, become most frequent of all.

Winds belonging to North-north-west and South-east quadrants, besides being comparatively infrequent, are, particularly in the case of the latter, mere appendages of the others. Thus, in Summer, when the North-east and South-west winds both turn somewhat landwards, winds from points in the South-east quadrant are occasionally seen, while those from a North-westerly direction tend to vanish. And in the Winter the reverse is the case, so that during the Winters of three years only 141 hours, equal to less than six days, of South-east quadrant wind are on record. Thus the favourite idea of prevailing South-east winds (carrying enormous supplies of moisture to the greater part of the South African table-land) proves to be as unfounded as the equally popular idea of continuous Northerly winds at Kimberley.

TABLE II.—MONTHLY COMPONENTS OF WIND FREQUENCY.

MONTH.	N.	E.	R.	ϕ
	hours.	hours.	hours.	° ′
January	− 84	−228	243	200 13
February	+127	− 96	159	127 5
March	+231	−267	353	139 8
April	+242	−554	604	156 24
May	+411	−896	986	155 22
June	+511	−987	1111	152 38
July	+639	−892	1097	144 23
August	+377	−628	732	149 2
September	−169	−555	580	196 56
October	−170	−379	415	204 9
November	− 82	−111	138	216 0
December	−225	− 67	235	253 25
3 Years	+1808	−5660	5942	162 17

Table II. gives the monthly components of wind frequency resolved along two directions at right angles, North and East; and the mechanical resultant, expressed in total hours during three years; also the vectorial angle made by the resultant measured from east in the direction N., W., S. In the Summer the resultants are short, indicating that the prevailing winds from North-east and South-west nearly balance each other; in the Winter the resultants are much longer. It is evident that these monthly resultants fall into two well-marked groups: the one, extending from September to January, comprising resultants in the third quadrant, with a mean angle of about 214°; the other, lasting from February to August, comprising resultants in the second quadrant, with a mean angle of about 146°. The greater number of hours of unbalanced wind, and the majority of months in the more Northerly group, attracts the final (annual) resultant to the second quadrant.

The monthly totals of wind frequency have been reduced to seasonal totals in Table III., the seasons being:—Spring, August to October; Summer, November to January; Autumn, February to April; and Winter, May to July.

From Table III. Table IV. has been computed, the object being to show the variation of the North-east and South-west winds separately in the course of the year. For this purpose, winds with a North-east com-

ponent are considered separately from those having a South-west component; North-west and South-east winds being divided equally between the two classes in forming the resultants. The directions are resolved North-west and North-east. All those from North-west are called positive, those from South-east negative. The angle ϕ is measured from North-east or South-west, and is reckoned positive when the extremity of the resultant is on the North-west side of North-east or South-east.

TABLE III.—Wind Frequency in Hours: Seasonal Totals.

Season.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
February to April	113	759	1333	297	88	85	43	91
May to July	320	578	542	130	37	35	21	27
August to October	231	607	926	232	115	106	71	93
November to January	84	434	1280	484	152	180	127	134

Season.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
February to April	116	443	935	818	526	441	121	132
May to July	79	400	510	752	752	928	805	541
August to October	172	768	905	837	604	430	258	188
November to January	206	815	949	790	360	238	61	124

TABLE IV.—Seasonal Components of Wind Frequency.

North-east Winds.

Season.	NW.	NE.	ϕ
	hours.	hours.	° ′
Autumn	+ 277	+2534	+ 6 14
Winter	+1230	1669	+36 23
Spring	+ 348	2058	+ 9 36
Summer	− 152	2411	− 3 36

South-west Winds.

Season.	NW.	SW.	ϕ
	hours.	hours.	° ′
Autumn	+ 796	+2758	+16 6
Winter	+1835	2527	+35 59
Spring	+ 726	3137	+13 2
Summer	+ 162	2974	+ 3 7

It seems that the prevailing winds have components directed at right angles to the coast, tending to the land in the Summer, when the mean temperature of the sea is less than that of the land, and tending from the land when the mean temperature of the sea is the greater.

This not extravagantly great variation of the prevailing directions is the nearest approach to a monsoon effect to be found in the winds of East London, although Ferrel's criteria would seem to be in many respects very well satisfied. Ferrel observes that "the strength of the

monsoon depends very much upon the nature of the surface of the continent. In the case of a perfectly flat continent with no highlands or mountain ranges, there would, of course, be an interchange of air between it and the ocean in case of difference of temperature, that of the lower part moving toward the warmer region, and that of the upper part away from it; but the monsoon effects would be comparatively small, and would not at all have the great strength of the surface winds which is usually observed. . . But if the surface of the continent is convex, or if it has highlands with long slopes, or the interior is in almost any way considerably elevated above sea-level, the tendency in the case of the summer monsoon to flow in from the ocean toward the interior of the continent, or the reverse in that of the winter monsoon, is very much increased."[1] Since the greater part of South Africa is a vast table-land lying between 2000 and 5000 feet above the sea, the mountains of Basutoland even reaching altitudes exceeding 10,000 feet, the geographical conditions for good monsoon effects appear to be favourable, and more especially because there is not, over the central table-land, any prevailing wind to be reversed as in the case of the South-west monsoon of Asia. Köppen does in fact depict a very considerable monsoon effect across the South-east coast of South Africa.[2] I do not know what observations he has relied upon for his directions (nor indeed was I aware that any observations have been hitherto available), but they are probably if not altogether incorrect, at any rate incomplete and therefore misleading. Taking into account the relative differences of temperature between land and water on the East and West coasts of South Africa, it seems to be likely, *a priori*, that the main transfer of air from sea to land (corresponding to the South-west monsoon of Asia) is to be looked for in the West, and for that reason is less intense in the South-east than it otherwise would be.

Table V. gives the diurnal variation of wind direction for the year. It represents the number of hours of wind at each hour of the day, from each of the sixteen directions. Speaking generally, the winds may be divided into two classes with respect to the diurnal variation: namely, those which have their maximum frequency after noon, and their minimum after midnight; and those in which the maximum frequency is at night, and the minimum by day. To the former class belong all winds springing from the direction of the sea between North-east and South-south-west, to the latter class all winds springing from the land side between West and North-east. Winds from the South-west and South-south-west form an intermediate class with a semi-diurnal oscillation, the minima falling near noon and midnight. The night minimum of West-south-west winds, however, is brief and not very pronounced, and the same is true of the day minimum of South-west winds. Thus the South-west and West-south-west winds form a link between the two classes mentioned above. It seems that the day maximum, which develops in intensity from South-east to South-south-west, bifurcates at South-west into two maxima close together, which, spreading apart at West-south-west, become again a single (but a night) maximum at West. No such bifurcation is apparent in the table during

[1] W. Ferrel, *A Popular Treatise on the Winds*, p. 195.
[2] See Bartholomew's *Atlas of Meteorology*, 1899, Plate 14.

TABLE V.—WIND FREQUENCY IN HOURS: DIURNAL VARIATION.

HOUR ENDING	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Total.
I	54	169	113	10	4	9	6	8	7	14	56	167	154	138	86	76	1071
II	63	163	107	9	4	6	5	12	9	13	48	187	144	157	89	61	1077
III	58	157	92	15	2	4	9	13	6	15	54	185	158	156	80	72	1076
IV	55	153	92	6	2	9	5	7	7	12	60	184	175	157	84	66	1074
V	55	146	85	5	2	11	1	6	6	6	68	190	183	159	94	60	1077
VI	60	133	78	7	6	10	5	3	4	7	65	181	194	171	100	53	1077
VII	43	121	92	7	8	8	4	5	4	6	79	192	171	181	100	52	1073
VIII	29	95	121	17	9	7	3	8	3	17	144	185	133	158	96	51	1076
IX	26	59	151	38	10	8	5	9	6	66	211	171	85	111	78	39	1073
X	14	46	173	55	11	15	7	12	19	143	233	138	57	63	59	30	1075
XI	12	19	191	84	26	12	11	13	31	231	230	96	31	25	36	16	1064
Noon	5	8	207	92	31	23	20	26	41	275	214	57	18	19	24	15	1075
XIII	6	9	212	97	36	37	20	21	51	299	189	43	12	12	14	13	1071
XIV	3	12	229	97	52	31	18	30	70	287	179	34	8	5	13	7	1075
XV	1	15	242	119	35	41	20	27	57	268	188	28	10	3	9	14	1077
XVI	4	30	267	105	35	36	19	26	52	233	204	31	13	3	7	10	1075
XVII	3	48	288	96	27	29	22	24	51	185	230	45	11	6	3	6	1074
XVIII	9	86	281	72	30	28	20	18	40	128	234	93	14	6	6	8	1073
XIX	32	115	243	60	24	22	12	16	35	75	192	154	36	18	9	28	1071
XX	39	141	197	55	13	14	11	18	20	52	141	174	76	46	26	45	1068
XXI	39	163	176	39	11	12	11	11	20	32	84	189	127	65	40	57	1076
XXII	44	159	166	23	6	12	9	11	16	25	66	165	137	111	59	65	1074
XXIII	51	170	140	22	3	13	9	12	11	18	71	145	147	130	59	72	1073
Midnight	43	161	138	13	5	9	10	9	7	19	59	163	148	137	74	69	1064
3 Years	748	2378	4081	1143	392	406	262	345	573	2426	3299	3197	2242	2037	1245	985	25,759

the transition from the day maximum of North-east winds to the day minimum of those from the North-north-east. At any rate, if it exist at all,—which seems not improbable,—it must be in some direction intermediate between North-east and North-north-east.

A good deal of light may be thrown upon these variations by resolving the hourly quantities under each direction into their harmonic components. The results of such a resolution are given to three terms in Table VI. This shows also two principal groups: one in which the

TABLE VI.—Harmonic Components of the Diurnal Variation of the Separate Directions.

Direction.	u_1.	u_2.	u_3.	V_1.		V_2.		V_3.	
	hours.	hours.	hours.	°	′	°	′	°	′
N.	29·200	3·953	4·070	71	2	271	34	279	55
NNE.	83·278	16·119	5·004	89	48	249	54	260	27
NE.	89·005	6·836	15·596	221	31	342	58	60	12
ENE.	51·348	12·316	2·523	240	34	56	18	353	38
E.	18·190	5·717	1·796	243	54	41	29	243	42
ESE.	13·323	5·849	2·798	233	7	25	0	202	3
SE.	7·987	3·009	·215	222	55	48	40	315	0
SSE.	9·168	4·398	·420	229	10	51	48	308	2
S.	26·047	10·459	2·892	233	36	40	47	250	58
SSW.	135·772	60·255	12·761	254	23	72	54	287	12
SW.	92·090	13·238	34·417	255	55	231	12	45	39
WSW.	73·072	37·735	10·653	62	57	235	25	342	55
W.	90·635	13·435	20·334	59	31	256	28	215	36
WNW.	90·419	10·082	17·838	49	6	255	22	172	3
NW.	47·919	6·211	7·800	39	4	220	49	156	56
NNW.	32·362	6·089	4·142	75	39	171	36	209	36

first harmonic term lies in the third quadrant, and the second harmonic term in the first quadrant; the other in which the first harmonic term lies in the first quadrant, and the second harmonic term in the third quadrant. To the former belong all winds springing from ENE., E., ESE., . . . SSW.; to the other belong all winds from WSW., W., WNW., . . . NNE. Winds from North-east and South-west are, so to speak, connecting links between the two. For while the first term changes at once from the first to the third quadrant between North-north-east and North-east, the second harmonic term passes first into the fourth quadrant, only reaching the first quadrant at East-north-east. Again, the first harmonic term changes at once from the first quadrant to the third between West-south-west and South-west, the second harmonic term does not pass from the third quadrant to the first until between South-west and South-south-west. In the case of both North-east and South-west winds, the third term is much greater than the second. On the whole, winds with a Westerly component have large third terms, winds with an Easterly component having—excepting only North-east winds—very small ones, approaching indeed vanishing point in the case of South-east and South-south-east. Mean values of the epochs and amplitudes of the two groups are:—

V_1 .	236° 48′	63° 52′			Hours.	Hours.
				u_1 .	37·405	63·841
V_2 .	48° 8′	237° 18′		u_2 .	14·568	13·375
V_3 .	280° 5′	233° 55′		u_3 .	3·344	9·977

The hourly components of wind frequency are given in Table VII. From this we gather that Northerly components prevail from 7 p.m. to 9 a.m.; Westerly from 7 p.m. to noon; while during the daylight hours they are more Southerly and Easterly. This is very nearly the opposite case to that of the central table-land. At Kimberley, for example, the wind components are Southerly and Easterly by night, Northerly and Westerly by day. The total range of the North component in three years is 636 hours, from + 339 to − 297; of the East component, 628

TABLE VII.—Hourly Components of Wind Frequency.

For the Hour ending	N.	E.	R.	φ
	hours.	hours.	hours.	° ′
I	+339	−397	522	139 30
II	+329	−423	536	142 8
III	+308	−445	541	145 19
IV	+300	−476	563	147 48
V	+292	−510	588	150 12
VI	+290	−526	601	151 8
VII	+261	−526	587	153 37
VIII	+181	−487	520	159 37
IX	+ 39	−401	403	174 27
X	− 97	−290	306	198 30
XI	−222	−156	271	234 54
Noon	−283	− 57	289	258 37
XIII	−297	+ 10	297	271 51
XIV	−296	+ 69	304	283 7
XV	−251	+ 98	269	291 20
XVI	−199	+102	224	297 9
XVII	−153	+ 93	179	301 8
XVIII	− 72	+ 48	87	303 41
XIX	+ 41	− 46	62	138 18
XX	+143	−150	207	136 22
XXI	+231	−227	324	134 31
XXII	+291	−288	410	134 42
XXIII	+318	−317	449	134 56
Midnight	+315	−358	477	138 39
3 Years	+1808	−5660	5942	162 17

hours, from − 526 to + 102. At Kimberley the range of the North component is 655 hours, from + 383 to − 272; of the East component, 801 hours, from + 334 to − 467. Thus, while the North components on both table-land and coast are very nearly equal in value (but opposite in sign), the East components are much less on the coast. It has been shown elsewhere [1] that the East component of the winds of Kimberley is a temperature curve: it is further evident that the East component of the winds of East London is also a temperature curve.[2] The turning-points of the East component come at the same time at Kimberley as those of temperature do, but are an hour later at East London. The explanation of the retardation in the case of the latter is perhaps that the effect of the inland temperatures take some time to act upon the coastal winds. Chambers notes the striking resemblance of the *North* component of the

[1] J. R. Sutton, "The Winds of Kimberley," *Transactions of the South African Philosophical Society*, vol 11, p. 75.

[2] Four degrees of temperature being the exact equivalent of 100 miles of wind.

winds of Kurrachee to an inverted temperature curve, but doubts the thermal character of the East component.[1]

The mechanical resultant of wind frequency reaches its greatest magnitude just before sunrise. There is a second maximum about 1 p.m. Minima appear about 11 a.m. and near sunset. On the table-land the sunset minimum comes very nearly at the same time as it does on the coast, but the other phases are earlier.

The vectorial angles made by the resultant are of considerable importance. Starting from the middle of the second quadrant just before midnight, the change for nearly the whole 24 hours is gradual in a forward direction, reaching almost the middle of the fourth quadrant at sunset. Then comes a sudden change to the first apparent position in the opposite quadrant. The angular velocity is greatest about 10 a.m., least about 10 p.m.

Since the mechanical resultant shifts its position by nearly 180° in less than an hour, it becomes an interesting question whether the interim motion is continuously forward or retrograde. Three tests are open to us: (1) to tabulate the actual directions during every few minutes between 5 and 7 p.m., and to compute their mechanical components and resultants; (2) to deduce the intermediate values of the North and East components graphically; (3) to determine the same by means of a suitable formula. I have no particular affection for the first course. A mere inspection of Table VII. shows that the North and East components very nearly vanish together at 6 p.m., therefore the resultant nearly vanishes, and consequently a little freehand rounding off of the curves might displace the extremity of the resultant into the first or third quadrant according to fancy. Obviously, if the extremity passes through the first quadrant, the apparent motion is direct; if through the third, it is retrograde. The third course has therefore been adopted, and values determined by the help of Bessel's sine series. But it seems clear that in a curve of this character many terms may be required to give anything like reasonable accuracy. In Table VIII. the amplitudes and epochs of the North and East components are given as far as the twelfth harmonic term, counting from 0·5 h. mean time of 22° 30′ E. The relatively great magnitude of the term of three hours' period in both series is worth notice. What is perhaps equally remarkable is the strength of the fifth and tenth harmonic terms. After the diurnal and semi-diurnal terms, the two series converge slowly; but it seems fairly certain that the North component vanishes in the hour ending near 18 h. 40 m., say at mean time 18 h. 10 m., and that at this time the East component is prominently negative, not differing greatly from − 10. The following are approximate interpolations:—

For the hour ending hr. min.	N.	E.	Angle. ° ′
18 30	−19	+ 8	292 50
18 40	0	−10	180 0
18 45	+ 6	−18	161 34

Thus the apparent motion during the hour in question is retrograde, and continues so, with diminishing speed, throughout the 19th, 20th, and 21st hours.

[1] "The Winds of Kurrachee," *Indian Meteorological Memoirs*, vol. 1, p. 271.

The resultants of Table VII. when plotted show that the curve obtained is almost an ellipse, with its major axis very nearly North-west to South-east, *i.e.* at right angles to the coast line. The curve is more elongated than the Kimberley curve. From the 19th to the 23rd hour the extremity of the resultant is moving almost in a right line away from the origin in a North-westerly direction.

TABLE VIII.—HARMONIC COMPONENTS OF WIND FREQUENCY.

	N. Comp.	E. Comp.		N. Comp.	E. Comp.
p	+75	−236		° ′	° ′
u_1	325·706	303·654	V_1	76 23	222 35
u_2	71·072	70·887	V_2	249 56	44 35
u_3	32·000	16·687	V_3	178 53	10 24
u_4	15·548	13·264	V_4	22 32	185 47
u_5	5·147	8·862	V_5	4 40	201 20
u_6	1·054	3·590	V_6	198 26	291 48
u_7	2·100	1·608	V_7	0 37	128 41
u_8	4·670	3·183	V_8	76 35	252 52
u_9	1·512	0·660	V_9	328 57	82 49
u_{10}	2·096	1·857	V_{10}	94 8	354 28
u_{11}	2·400	0·464	V_{11}	28 48	38 5
u_{12}	0·333	1·000	V_{12}	90 0	90 0

The epochs given in Table VIII. urge the essentially thermal nature of the East component. The epochs of the table-land temperatures are in fact earlier than those of the East component at East London by the following quantities :—

First harmonic term . . . . 65 minutes.
Second ,, ,, ... 66 ,,
Third ,, ,, ... 52 ,,
Fourth ,, ,, ... 66 ,,

These are as closely concordant as those of the temperature and East component of the table-land itself. Note, however, that the clock at Kimberley is only 8 minutes slower than local mean time, whereas at East London it is 22 minutes slower. The effect of this (which does not qualify the argument) is to increase each of the above periods by 14 minutes. As to the North component, there is not, any more than there is at Kimberley, any connection between it and the harmonic constants of either temperature or pressure, saving a possible pressure influence in the third harmonic term.

Table IX. is designed to show the variation of the North-east and South-west components of wind frequency, considered separately. The numbers of hours of wind, tabulated to sixteen directions, have been resolved along the four directions—North-east, North-west, South-west, South-east, and two partial resultants formed, one including all winds with a South-west component, the other including all winds with a North-east component, exactly in the same way as in Table IV. Herein are some remarkable points of similarity between the North-east and South-west curves. We see that both are described the same way round, *i.e.* both veer with the sun. Their turning points are nearly at the same hours. Generally speaking, the angular velocity of both partial resultants

varies together. Between midnight and sunrise the orbital movements are almost radial—the North-east one towards, the South-west one away from, the origin. It is curious, too, how the angularities of one curve are reproduced upon the other hour by hour, of which the most striking pair is found in the concavity between III. and V. This feature is indeed sufficiently marked to temporarily reverse the angular velocity. It ought to be worth investigation whether it is merely an irregularity due to the shortness of the record, or whether it is connected with the morning barometric minimum. According to Table IX., the angular space described by the North-east partial resultant is nearly 46°, that of the South-west partial resultant rather more than 59°. The turning points are near the times of maximum and minimum temperature.

TABLE IX.—Hourly Partial Resultants of Wind Frequency.

For the Hour ending	NE. Resultant.			SW. Resultant.		
	NW.	NE.	φ	NW.	SW.	φ
	hours.	hours.	° ′	hours.	hours.	° ′
I	+198	+352	+29 21	+323	+393	+39 25
II	+193	339	+29 39	+338	406	+39 47
III	+201	322	+31 58	+365	419	+41 4
IV	+186	308	+31 8	+362	433	+39 54
V	+184	292	+32 15	+383	446	+40 39
VI	+173	278	+31 54	+404	445	+42 14
VII	+157	269	+30 16	+400	457	+41 12
VIII	+131	274	+25 33	+342	490	+34 55
IX	+ 85	284	+16 40	+223	540	+22 26
X	+ 39	301	+ 7 23	+ 98	575	+ 9 40
XI	− 19	324	− 3 21	− 28	590	− 2 43
Noon	− 56	339	− 9 23	−104	580	−10 10
XIII	− 80	359	−12 34	−137	562	−13 42
XIV	− 91	383	−13 22	−167	544	−17 4
XV	− 95	412	−12 59	−152	520	−16 18
XVI	− 81	437	−10 30	−132	505	−14 39
XVII	− 67	456	− 8 22	−107	498	−12 25
XVIII	− 35	468	− 4 17	− 50	486	− 5 52
XIX	+ 31	463	+ 3 50	+ 31	467	+ 3 48
XX	+ 87	437	+11 15	+120	442	+15 11
XXI	+124	424	+16 18	+200	421	+25 25
XXII	+153	399	+20 59	+257	396	+32 59
XXIII	+170	388	+23 40	+279	388	+35 43
Midnight	+171	363	+25 14	+305	393	+37 49

In Table X. will be found the monthly components of the winds of East London when direction and velocity are considered together. In the main it reproduces the features of Table II., but with important modifications. As in that table, the North component is positive from February to August, negative from September to January. July also is the month in which the North component attains its greatest positive value. But while the small numerical value of this component in November, as compared with October and December, is common to both tables, a large value in September is peculiar to Table X. And further, while the monthly quantities of Table II. increase gradually from February to July, in Table X., February, March, and May are nearly equal, while the April quantity is the smallest of any.

The East components of Tables II. and X. correspond fairly well. They stand in nearly the same order, and have maxima and minima at the same times. The small negative value of the East component of wind direction in February, however, is actually exaggerated into a positive value of the East component of wind movement. One result of this is to transfer the minimum component of hours in February to the minimum component of miles in January.

With the exception of the February and March quantities, the vectorial angle is uniformly greater in Table X. than it is in Table II. In February the angle is more than 55° behind the corresponding angle of frequency, and in March it is 22° behind.

TABLE X.—Monthly Components of Wind Movement.

Month.	N.	E.	R.	ϕ
	miles.	miles.	miles.	° ′
January	− 1,970	− 3,400	3,929	210 5
February	+ 4,869	+ 1,597	5,124	71 51
March	+ 4,969	− 2,552	5,586	117 11
April	+ 1,810	− 8,919	9,101	168 32
May	+ 4,886	− 17,540	18,208	164 26
June	+ 7,179	− 19,999	21,248	160 15
July	+ 10,094	− 17,201	19,944	149 36
August	+ 5,195	− 12,191	13,252	156 55
September	− 6,233	− 11,646	13,209	208 9
October	− 5,739	− 7,837	9,714	216 13
November	− 4,473	− 3,022	5,389	235 57
December	− 6,203	− 1,192	6,317	259 7
3 Years	+ 14,384	− 103,902	104,893	172 7

An explanation of the disparities between Tables II. and X. is readily furnished by Table XI. Thus we see that the velocity of North-east winds is relatively very great in February, and therefore the North and East components of movement tend strongly in a positive direction. Again, in April, winds with high velocities are found chiefly among those with a Southerly component. The Southerly component of frequency is pretty much the same in January as it is in November, while the Westerly component is twice as great in January. The relatively great value of the corresponding November components of movement is shown by Table XI. to be due to the greater velocity of South-westerly winds. And so forth.

It further appears from Table XI. that winds from North to West-north-west have their mean minimum velocity in Summer; those from West to South-west in Autumn; the minimum velocity of all the rest coming in Winter. The mean maximum velocity falls in Winter to all winds from N., NNW., . . . WSW.; in Summer to all from S., SSE., . . . NNE.; and in Spring to winds from NNE., NE., SSW., and SW.

North-east winds have the greatest average velocity; South-south-west and South-west coming next. Northerly and South-easterly winds have the least average velocities. Wherefore, on the whole, the higher the frequency of a given wind the greater will be its mean velocity.

The hourly components of wind movement are given in Table XII.

TABLE XI.—ANNUAL VARIATION OF WIND VELOCITY, IN MILES PER HOUR, FROM EACH DIRECTION.

MONTH.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Mean.
January	8·8	16·7	24·4	19·7	12·2	9·8	9·3	9·6	13·5	22·5	22·5	18·0	16·0	11·3	9·3	10·7	19·6
February	10·8	19·1	27·5	17·7	11·6	11·6	12·8	10·1	14·0	19·3	21·5	16·1	13·1	15·3	9·4	10·9	19·6
March	9·7	17·6	24·8	17·5	15·6	12·1	9·2	6·3	13·1	22·0	22·0	18·9	15·2	12·3	12·5	11·1	19·2
April	11·2	16·4	23·2	19·9	14·0	8·2	13·1	13·9	15·8	24·3	23·2	18·9	14·8	13·4	12·7	11·0	18·1
May	12·6	16·2	22·9	17·0	9·5	12·0	9·7	8·7	10·5	18·8	22·9	22·2	20·4	14·8	15·7	14·4	18·6
June	13·7	17·5	21·0	15·5	12·6	8·0	8·3	16·0	14·8	16·0	22·8	25·1	21·3	16·8	17·3	14·3	18·5
July	13·2	14·5	24·9	13·2	8·6	7·1	9·5	5·3	9·0	17·8	21·4	23·1	20·7	16·4	18·2	15·4	18·3
August	13·7	19·3	26·3	13·8	11·7	11·0	16·7	13·5	10·9	24·3	22·9	24·0	21·2	14·6	15·6	13·2	19·7
September	11·4	18·7	28·1	17·9	12·9	12·2	12·8	11·4	16·0	27·9	25·7	20·6	17·2	14·4	15·2	11·6	21·3
October	11·8	19·6	29·8	22·2	21·7	15·8	13·5	13·3	15·6	28·9	26·4	23·5	19·2	15·2	12·1	9·6	23·5
November	11·2	17·7	26·8	21·2	16·0	15·7	16·3	11·1	16·4	29·8	28·0	23·3	17·9	14·5	11·5	7·0	22·4
December	9·8	17·3	26·4	17·9	15·8	15·5	15·9	15·2	18·3	26·7	27·3	18·5	14·3	13·3	10·2	11·0	21·1
Year	12·4	17·6	25·8	18·8	14·9	12·9	13·6	12·3	14·7	24·4	24·1	21·1	18·2	14·8	16·0	13·0	20·0
Feb. to April	10·8	17·6	25·3	18·2	12·9	11·3	12·2	10·6	14·3	21·6	22·2	18·1	14·5	13·3	11·5	11·0	19·0
May to July	13·2	16·0	23·1	15·6	10·9	8·8	9·2	11·6	11·5	17·7	22·4	24·3	20·8	16·0	17·3	14·6	18·5
Aug. to October	12·8	19·2	28·3	19·0	16·9	13·2	14·1	12·8	14·4	27·6	25·6	22·5	19·5	14·7	15·0	12·3	21·5
Nov. to Jan.	10·0	17·4	25·8	19·8	15·0	14·3	14·6	13·3	16·4	26·3	25·5	19·8	16·2	13·1	10·5	9·4	21·0

They harmonise with the components of frequency, excepting that they tend rather more Westerly and Southerly. Also the maximum and

minimum values of the resultant of wind movement do not fall at quite the same times as those of frequency. It is interesting to observe how the angular velocities of the resultants differ in the two cases. Chiefly it is to be observed that the extremity of the resultant of movement reaches the limit of its angular excursion, and begins to regress practically an hour earlier than the other resultant does. The angle described by the total resultant of wind movement is 171°, or about 2° greater than that of frequency. The upshot of Tables VII. and XII. is, that there are 5942 hours of unbalanced wind moving from N. 72° W. with an average velocity of 17·5 miles an hour; 104,892 miles from N. 82° W., which, considered as a whole movement, gives a mean residual velocity of 4·1 miles an hour. This is fully twenty times as great as the residual velocity on the table-land.

TABLE XII.—Hourly Components of Wind Movement.

For the Hour ending	N.	E.	R.	V.	ϕ
	miles.	miles.	miles.	miles per hr.	° ′
I	+4,785	-7,777	9,131	8·5	148 24
II	+4,463	-8,227	9,359	8·7	151 31
III	+3,957	-8,330	9,222	8·7	154 35
IV	+3,889	-8,600	9,438	8·8	155 40
V	+3,909	-9,335	10,124	9·4	157 17
VI	+3,873	-9,496	10,255	9·5	157 42
VII	+3,418	-9,336	9,942	9·3	159 53
VIII	+1,956	-8,626	8,845	8·2	167 13
IX	- 244	-6,657	6,662	6·2	182 6
X	-2,403	-4,603	5,193	4·8	207 34
XI	-4,518	-2,891	5,364	5·0	237 23
Noon	-5,264	-1,283	5,418	5·0	256 18
XIII	-5,790	- 143	5,792	5·4	268 35
XIV	-5,979	+ 897	6,046	5·6	278 32
XV	-5,117	+1,470	5,324	4·9	286 2
XVI	-3,865	+1,738	4,238	3·9	294 13
XVII	-2,386	+1,711	2,936	2·7	305 39
XVIII	-1,269	+ 642	1,422	1·3	296 50
XIX	+ 797	- 819	1,143	1·1	135 49
XX	+2,565	-2,600	3,652	3·4	135 21
XXI	+3,819	-3,796	5,385	5·0	134 49
XXII	+4,747	-5,147	7,002	6·5	137 19
XXIII	+4,635	-5,831	7,449	7·0	141 31
Midnight	+4,406	-6,863	8,156	7·7	147 18
3 Years	+14.384	-103,902	104,892	4·1	172 7

Table XIII. gives the mean annual velocity at each hour of winds from each direction. It serves to explain the nature of the relationship between Tables VII. and XII. There is a good deal of irregularity from one hour to the next, more especially in the case of infrequent winds, due for the most part to the shortness of the period under review. It is remarkable that North-east winds have their maximum velocity just after noon, and their minimum just before sunrise; while South-west winds have their minimum before mid-day, and their maximum after midnight. It is curious, too, that South-south-west and West-south-west winds have their maximum velocities at the usual time, not long after mid-day.

Table XIV. gives the mean velocity at each hour for each month. The minimum velocity occurs about III. There seems to be another,

much less prominent, minimum about XXIII. The time of the principal maximum is somewhat indefinite, owing to the curious slackening of

TABLE XIII.—DIURNAL VARIATION OF WIND VELOCITY, IN MILES PER HOUR, FROM EACH DIRECTION.

For the Hour ending	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Mean.
I	12·7	16·7	20·2	10·1	16·2	15·1	14·2	13·1	12·7	16·5	25·9	22·1	18·9	15·6	17·2	13·3	17·9
II	12·3	16·7	19·4	10·3	18·2	11·2	21·8	12·4	13·6	18·5	28·5	21·5	18·1	16·0	17·3	12·6	17·9
III	12·4	16·4	18·9	11·3	19·5	10·2	17·1	14·8	17·5	17·1	27·0	20·3	18·2	15·3	16·8	12·1	17·4
IV	12·1	16·0	19·4	9·5	21·5	11·4	27·0	17·0	13·0	17·8	24·0	19·8	18·3	15·0	16·5	12·1	17·2
V	12·3	16·7	19·0	12·8	14·0	15·6	46·0	22·2	12·0	18·5	23·8	19·6	18·4	16·0	16·6	12·5	17·6
VI	12·7	17·1	19·7	15·7	13·7	15·1	22·0	21·0	13·5	21·4	24·6	19·7	18·1	15·7	16·5	11·5	17·6
VII	12·5	16·2	21·0	13·4	14·6	17·0	21·3	25·0	11·8	17·7	22·7	20·4	17·1	15·9	16·1	11·8	17·6
VIII	13·0	16·3	22·8	20·0	12·8	17·7	26·0	19·1	20·0	21·4	22·3	20·8	18·3	14·9	15·5	10·6	18·4
IX	12·3	19·0	25·3	21·8	9·2	17·6	22·6	14·9	14·0	21·9	21·3	20·6	18·4	11·9	14·2	10·5	19·0
X	11·0	18·0	25·5	18·4	12·8	14·3	17·9	11·1	13·2	21·2	19·9	22·2	18·9	8·9	11·1	10·7	19·3
XI	8·7	17·3	28·0	21·3	12·9	16·6	12·5	14·5	14·6	22·6	21·3	25·3	22·8	8·1	13·9	14·3	21·6
Noon	12·0	17·2	28·9	20·7	14·5	12·7	12·2	11·0	13·6	23·9	21·2	28·2	27·6	15·4	15·1	16·1	22·3
XIII	11·0	15·6	30·9	20·5	15·6	11·7	13·8	11·4	15·9	25·3	22·8	27·6	26·9	21·9	21·2	17·6	23·4
XIV	18·7	16·7	31·8	21·7	15·0	12·9	11·0	13·0	14·7	27·6	25·0	30·0	21·1	16·4	20·4	24·0	24·7
XV	8·0	24·2	30·1	20·2	14·8	12·5	11·3	10·9	14·8	27·9	24·2	28·2	26·3	14·3	18·0	16·8	24·1
XVI	13·3	25·0	30·4	19·8	14·5	12·8	11·4	11·2	14·3	28·0	25·9	26·0	18·0	9·3	19·6	17·6	24·5
XVII	13·3	24·0	28·4	19·3	16·2	12·9	9·2	9·8	13·3	26·1	25·5	20·4	21·3	15·0	18·7	16·5	23·7
XVIII	10·1	18·6	27·7	17·7	14·6	11·9	10·2	7·7	15·2	24·5	26·7	19·0	13·9	11·3	13·2	11·8	22·4
XIX	11·2	20·3	26·7	16·6	15·8	11·2	11·7	10·1	13·8	21·8	27·5	19·2	13·7	11·8	12·1	13·5	21·1
XX	12·0	20·3	25·7	16·1	18·2	10·9	11·7	12·2	16·0	16·8	26·3	21·3	16·4	12·7	13·1	14·2	20·1
XXI	12·4	17·9	22·8	16·6	15·6	10·9	13·4	12·6	13·5	15·4	26·1	19·6	16·5	13·3	15·4	14·4	18·3
XXII	13·1	18·3	21·9	16·9	17·7	11·1	12·2	11·4	17·8	14·2	26·8	20·8	18·2	14·4	16·3	14·2	18·4
XXIII	12·4	16·1	21·0	15·4	20·3	12·9	15·7	10·7	20·1	14·4	24·7	20·8	17·5	15·5	16·8	13·9	17·7
Midnight	13·2	15·9	20·0	12·2	16·6	12·1	16·0	11·9	20·3	14·7	26·3	21·1	18·4	15·4	16·5	13·3	17·8
Year	12·4	17·6	25·8	18·8	14·9	12·9	13·6	12·3	14·7	24·4	24·1	21·1	18·2	14·8	16·0	13·0	20·0

velocity between XIV. and XV. This is not an accidental phenomenon, because it is plainly present in nearly every month. It is also plain in

Table XIII., since seven of the sixteen directions have velocities at 2.30 p.m. less than the velocities at 1.30 p.m. and 3.30 p.m.; two directions only have velocities at 2.30 p.m. greater than the velocities at adjacent hours, and, in both, the velocity at 1.30 p.m. is less than it is at either 0.30 or 2.30 p.m. (*i.e.* the normal slackening, if we may so call it, comes an hour earlier).

This slackening of velocity seems to depend in some way upon the behaviour of the North and East components of wind frequency, or of wind movement—probably the latter. For just after XIII. the North component reaches its greatest Southerly excursion and begins to return,

TABLE XIV.—MEAN VELOCITY OF THE WIND IN MILES PER HOUR.

For the Hour ending	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
I	16·4	16·8	16·5	15·6	18·5	19·9	19·2	18·1	19·2	19·2	17·3	18·6	17·9
II	16·0	16·2	17·1	16·1	18·4	20·0	19·6	18·5	19·2	19·1	17·3	17·2	17·9
III	15·6	15·8	16·9	15·9	17·1	19·0	18·5	18·4	19·0	18·9	16·8	16·6	17·4
IV	15·9	15·5	16·5	15·3	17·2	19·2	18·2	18·0	18·2	19·4	16·9	16·4	17·2
V	16·4	15·9	16·3	15·6	17·6	19·9	17·8	18·7	18·5	20·1	17·1	16·8	17·6
VI	16·0	16·3	15·7	15·6	17·6	19·8	18·1	19·0	18·2	20·1	17·9	16·6	17·6
VII	16·3	16·3	14·9	15·5	17·5	19·5	18·0	19·3	17·6	19·8	18·9	17·1	17·6
VIII	18·2	17·0	15·6	15·1	17·3	19·1	17·8	18·8	18·1	22·7	21·6	19·5	18·4
IX	20·0	18·4	17·5	16·2	17·3	16·3	16·3	18·2	19·7	24·2	23·7	20·8	19·0
X	19·8	18·3	18·3	16·8	17·0	14·8	16·2	18·9	20·6	24·5	24·3	21·8	19·3
XI	22·9	20·7	19·5	19·3	18·9	16·7	18·6	21·4	23·4	27·4	26·3	24·2	21·6
Noon	23·0	22·4	21·3	20·1	19·6	16·9	19·3	22·0	24·0	27·5	26·9	24·6	22·3
XIII	24·2	23·3	23·3	21·0	21·0	18·0	19·1	23·4	24·6	29·1	27·8	26·5	23·4
XIV	24·4	24·9	24·3	22·7	21·8	19·4	20·3	24·2	26·6	30·7	29·2	27·8	24·7
XV	24·3	24·5	23·7	23·0	20·9	19·1	19·6	23·5	26·7	29·6	28·1	26·2	24·1
XVI	24·6	25·0	23·9	24·0	21·5	19·1	20·2	23·6	27·2	30·4	28·3	26·5	24·5
XVII	23·7	24·6	24·0	22·7	20·9	18·6	18·9	22·1	26·3	29·5	28·1	24·7	23·7
XVIII	22·2	23·6	22·7	21·4	19·1	17·6	18·0	19·8	25·0	27·9	27·6	24·3	22·4
XIX	21·3	22·8	22·3	19·8	18·8	17·2	17·2	17·8	22·2	25·4	25·1	23·6	21·1
XX	20·1	21·2	21·1	18·9	18·2	18·4	17·4	17·5	21·1	22·1	23·2	21·6	20·1
XXI	18·3	18·3	18·9	17·0	17·1	18·4	16·9	16·9	18·6	19·9	20·3	19·3	18·3
XXII	17·5	17·7	18·0	16·3	17·7	18·5	18·4	18·1	19·2	20·0	19·5	19·8	18·4
XXIII	16·7	17·0	17·3	15·7	17·3	18·8	18·1	17·5	18·8	18·6	18·1	18·4	17·7
Midnight	16·4	17·3	16·5	15·5	18·3	19·2	18·4	17·8	18·9	18·6	17·5	18·6	17·8
Year	19·6	19·6	19·2	18·1	18·6	18·5	18·3	19·7	21·3	23·5	22·4	21·1	20·0
Max. Hourly Velocity	59	69	58	62	60	55	79	62	79	74	67	75	79
Max. Day.	883	1019	823	871	892	874	996	919	1006	1099	950	935	1099
Min. Day.	211	129	197	142	210	252	260	171	218	228	232	186	129

while the East component reaches its greatest Easterly excursion between XV. and XVI. The same phenomenon occurs elsewhere. At Calcutta the North component reaches its first Southerly limit just after XI., while the East component reaches its greatest Westerly excursion a little before XIV. And we find at this station also a slackening of wind velocity about noon. Blanford first noticed this. He remarks that "the somewhat anomalous interruption of the regularity of the curve about noon appears in the curve of most months. . . . It coincides on an average with that tendency of the wind to shift to the North-west."[1]

There is in the same way a slight slackening of the velocity at

[1] "The Winds of Calcutta," *Indian Meteorological Memoirs*, vol. 1, p. 9.

Kurrachee about XVI., say an hour after the North component passes its maximum Southerly swing. On the other hand, at Córdoba, the North component is farthest North about XVI., and there is not any corresponding slackening of the velocity at all.[1] Also at Kimberley the North component is farthest North between X. and XI., without any apparent effect upon the velocity. But it is curious that at Kimberley there is a temporary increase of velocity in the hours before midnight, following immediately upon the extreme Southerly excursion of the North component.

TABLE XV.—Mean Velocity of Winds in the NE. and SW. Quadrants.

For the Hour ending	NE. Quadrant.		SW. Quadrant.	
	Total Hours.	Mean Velocity.	Total Hours.	Mean Velocity.
		m. per h.		m. per h.
XIII	360	25·9	594	23·9
XIV	393	26·5	578	25·4
XV	412	25·7	551	25·2
XVI	441	26·1	533	25·5
XVII	462	25·3	522	24·0
XVIII	478	23·4	509	23·5

In this connection it is interesting to consider the velocities of North-east and South-west winds at East London separately. Combining all the winds in the North-east quadrant, and all in the West-south quadrant, we get Table XV., from which it appears that the slackening of the velocity comes a little earlier in the South-west quadrant than it does in the other. And bearing directly upon this is the fact, that the South-west partial resultant turns Northwards slightly earlier, and rather more abruptly than the North-east partial resultant does. Another interesting fact is that the minimum velocity near midnight comes near the time when the vane has completed its Northerly swing.

The mean velocity is exactly 20 miles per hour. The maximum velocity observed in any whole hour during the three years was 79 miles, in July and September. It seems that velocities exceeding 70 miles per hour are to be anticipated in any month during the second half of the year. The maximum velocity observed in any one day was 1099 miles in October, equal to an average for the day of nearly 46 miles per hour. A velocity exceeding 800 miles per day is possible in any month. Calms are rare, the longest on record probably not more than four hours long. The minimum run of the anemometer was 129 miles in a day, *i.e.* 5·4 miles per hour, although it is only now and then that there is a day in which the average velocity is less than 10 miles per hour.

The velocities in the last column of Table XIV. may be represented by the formula :—

$$\begin{aligned} V = 20{\cdot}0 &+ 3{\cdot}443 \sin (n15^\circ + 239^\circ{\cdot}5) \\ &+ 1{\cdot}127 \sin (n30^\circ + 32^\circ{\cdot}8) \\ &+ 0{\cdot}129 \sin (n45^\circ + 125^\circ{\cdot}6) \\ &+ 0{\cdot}138 \sin (n60^\circ + 114^\circ{\cdot}8) \\ &+ \ldots \end{aligned}$$

counting from 0·5 h. With the exception of the third, all the epochs are later than those of the table-land.

[1] See *Anales de la Oficina Meteorologica Argentina*, vol. 9, pt. 2, p. 369.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 18, 1905.

Ordinary Meeting.

Capt. D. Wilson-Barker, F.R.S.E., President, in the Chair.

Patrick A. Cunningham, H.M. Naval Yard, Hong-Kong;
Charles Carkeel James, M.Inst.C.E., Municipal Offices, Bombay;
John Arnallt Jones, M.D., Heathmont, Aberavon, Glamorgan;
John Owen Jones, Shortmead Street, Biggleswade;
Charles James Thompson, Warren Bank, Brampton;
Gilbert Thomas Walker, M.A., F.R.S., Meteorological Office, Simla; and
Edward Fawcett White, F.R.A.S., Ashley Road, Bristol,
were balloted for and elected Fellows of the Society.

January 18, 1905.

Annual General Meeting.

Capt. D. Wilson-Barker, F.R.S.E., President, in the Chair.

Mr. A. Chandler and Mr. R. G. K. Lempfert were appointed Scrutineers of the Ballot for Officers and Council.

The Report of the Council having been read, it was proposed by the President, seconded by Mr. F. C. Bayard, and resolved: "That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*." [The Report will appear in the next number of the *Quarterly Journal.*]

It was proposed by Mr. W. B. Tripp, seconded by Capt. A. Carpenter, and resolved: "That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year, and also to the Auditors."

It was proposed by Dr. W. N. Shaw, seconded by Capt. W. F. Caborne, and resolved: "That the thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

The President then delivered an Address on "The Connection of Meteorology with other Sciences" (p. 85).

It was proposed by Dr. H. R. Mill, seconded by Mr. R. Inwards, and resolved: "That the thanks of the Society be given to Capt. D. Wilson-Barker for his services as President, and for his Address, and that he be requested to allow the Address to be printed in the *Quarterly Journal*.

"That a copy of this Resolution be engrossed, and presented to Capt. Wilson-Barker."

The Scrutineers then declared the following to be the Officers and Council for the ensuing year:—

PRESIDENT.

RICHARD BENTLEY, F.S.A., F.L.S., F.R.G.S.

VICE-PRESIDENTS.

FRANCIS DRUCE, M.A., F.R.G.S.
JOHN HOPKINSON, Assoc.Inst.C.E., F.R.M.S.
HENRY MELLISH, D.L., J.P., F.R.G.S.
Capt. DAVID WILSON-BARKER, F.R.S.E., F.R.G.S.

TREASURER.

CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

SECRETARIES.

FRANCIS CAMPBELL BAYARD, LL.M.
HUGH ROBERT MILL, D.Sc., LL.D., F.R.S.E., F.R.G.S.

FOREIGN SECRETARY.

ROBERT HENRY SCOTT, M.A., D.Sc., F.R.S.

COUNCIL.

Capt. WARREN FREDERICK CABORNE, C.B., F.R.G.S., F.R.A.S.
RICHARD HENRY CURTIS.
HENRY NEWTON DICKSON, M.A., D.Sc., F.R.S.E., F.R.G.S.
WILLIAM HENRY DINES, B.A.
WILLIAM ELLIS, F.R.S., F.R.A.S.
Capt. MELVILLE WILLIS CAMPBELL HEPWORTH, C.B., F.R.A.S.
RICHARD INWARDS, F.R.A.S.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
EDWARD MAWLEY, F.R.H.S.
Sir JOHN WILLIAM MOORE, M.D., F.R.C.P.I.
WILLIAM NAPIER SHAW, M.A., D.Sc., F.R.S.
CHARLES THOMSON REES WILSON, M.A., F.R.S.

Capt. D. WILSON-BARKER having left the Chair, it was taken by Mr. R. BENTLEY, the newly elected President, who thanked the Fellows for having elected him to the office.

February 15, 1905.

Ordinary Meeting.

RICHARD BENTLEY, F.S.A., President, in the Chair.

Capt. GEORGE CAIE, 1 Dunolly Gardens, Ibrox, Glasgow;
GEORGE ANTHONY FERNANDEZ, Singapore, Straits Settlements;
ERNEST HOLT, 6 York Terrace, Frimley Road, Camberley;
ARTHUR EDWARD MITCHELL, Rathmines, Dublin; and
Capt. JOHN MILNE GARDINER SHAW, 32 Bridge Street, Montrose,
were balloted for and elected Fellows of the Society.

A letter was read from Dr. Shaw with reference to the Conference of Directors and Superintendents of Meteorological Institutes and Observatories to be held at Innsbruck in September next (p. 54).

The President presented to Capt. Wilson-Barker the illuminated copy of the Resolution of Thanks adopted at the Annual General Meeting.

The following communications were read:—

(1) "REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1904." By EDWARD MAWLEY, F.R.H.S. (p. 97).

(2) "OBSERVATIONS MADE DURING A BALLOON ASCENT AT BERLIN, SEPTEMBER 1, 1904." By HERMANN ELIAS, Ph.D., and J. H. FIELD, B.Sc., F.R.Met.Soc. (p. 125).

(3) "THE WINDS OF EAST LONDON. CAPE COLONY." By J. R. SUTTON, M.A., F.R.Met.Soc. (p. 133).

CORRESPONDENCE AND NOTES.

The Anomalies of the Weather in Iceland, 1851-1900, and their Relation to the Simultaneous Weather Anomalies in North-Western Europe.[1] By J. Hann. [Translated from the *Meteorologische Zeitschrift*, February 1905, by Dr. R. H. Scott, F.R.S. All the values are in English measures.]

Teisserenc de Bort has introduced, for the established great maxima and minima of pressure for the extra-tropical zone, the fortunate expression of "centres of action for the atmosphere." For the whole of Western Europe these are represented by the subtropical pressure maxima about the Azores, and the deep barometrical minima around Iceland. The best cartographical representation of this last has been given by G. Rung.[2] The weather anomalies of Western Europe are closely and causally related to the occasional extensions of this area.

The following short article may furnish a contribution to the establishment of these relations.[3]

The inquiry is based mainly on the means of pressure and temperature for Stykkisholm, 1846-1900. This long series of records, embracing all elements, was in great measure carried out by one single man, Olaf Thorlacius, who observed from November 1845 to the end of 1891, and has left the record for this long period without any gap. It is, therefore, of very special interest because Stykkisholm is in Iceland, in lat. 65° 5′ N. and long. 22° 46′ W., and belongs to one of the two "action centres" of the North Atlantic, *i.e.* to the deep barometrical minima to which the mild oceanic climate of Northern and Central Europe owes its origin. In fact the results of the pressure observations at Stykkisholm from 1846-1900 allow us to trace the variations in the intensity of the action of this atmospheric centre for fifty-five years, and so to

[1] A short extract from a paper in the *Abhandlung in den Sitzungsber. der Wiener Akad.*, vol. 113, January 1904.

[2] *Répartition de la pression atmosphérique sur l'océan Atlantique.* Copenhague, 1894. 13 charts royal folio.

[3] I was always convinced that by the collection of the results of several long-continued series of observations, we should ultimately throw light on the alternating relations of weather anomalies of districts on the earth's surface far distant from each other. At the same time the results of such long-continued series of observations furnish us with material for the investigation of periodicity in the sequence of weather anomalies, a subject which is at present attracting much interest. The *Met. Zeitschrift* contains many papers from me in which I hope I have supplied material for such investigation. Unfortunately such discussions of long-period observations which require not only much work and trouble, but also, if they are to be of scientific value, require careful criticism and accurate treatment of the material, and are often of low value, as being only a statistical and climatological contribution, yet these are the only sure bases for all discussions of the long-period observations which may influence the condition of our atmosphere.

feel the pulse of this main factor of the climate of North-west and Central Europe.

The tables of monthly means and of the deviations are given at the end of my paper. The stations of Greenwich and Brussels have been taken for comparison of the anomalies of temperature and pressure. The temperature means for Greenwich 1851-1900 in centigrade degrees are to be found in Angot's *Études sur le climat de la France : Température* (*Annales du Bureau Central, Mémoires de* 1900). The variations of temperature and rain in Brussels, in so far as they have been employed in this investigation, are to be found in the *Annuaire Météorologique* for 1902, published by A. Lancaster, Brussels, 1902. They have been subjected to some small corrections in order to reduce them to the means from 1851-1900. The variations of pressure and temperature at Vienna have been taken from my paper on "Die Meteorologie von Wien."

A. *The simultaneous Anomalies of the Winter Months at Stykkisholm, Greenwich, Brussels, and Vienna.*

If clearly marked relations exist between the weather anomalies in Iceland and those in North-west and Central Europe, these will be more easily detected in the winter months ; comparative tables have been prepared in this sense, but are not reproduced here.

The results of comparisons of the simultaneous deviations are :—

1. *Pressure Variation.*—In December we find only ten out of fifty variations of pressure at Stykkisholm in the same sense as those at Brussels and Vienna. These last two stations almost always coincide in the sense of their variation. The probability of an opposition in the pressure deviation at Stykkisholm and that in North-west and Central Europe is therefore very great in December, amounting to 0·80. A similar comparison for January and February gives the following result :—

Probability of a contrast in the variation of pressure at Stykkisholm as compared with North-west and Central Europe—

December.	January.	February.	Mean.
0·80	0·58	0·74	0·70

The probability of a deviation in the opposite sense is therefore more than twice as great as of a deviation in the same sense. The depression of the pressure minimum in Iceland appears therefore to be associated with a rise of pressure in North-west and Central Europe in 70 per cent of the cases. From the physical point of view this result is encouraging, as the deepening of a stationary barometrical minimum must theoretically bring about a rise of pressure outside it.[1]

2. *Temperature Deviation.*—With temperature the results are not nearly so decided.

	Dec.	Jan.	Feb.	Total.
Temperature deviation, similar . . .	22	15	21	58
,, ,, drops casual . .	28	32	24	84
Result indeterminate	...	3	5	8

Accordingly, in the majority of cases, the temperature deviation at Stykkisholm is opposite to that in North-west Europe, so that we can only count with slight certainty on an opposition. The result can hardly be expected to be otherwise, as the temperature anomaly of a single station is often due to local causes.

[1] We may draw attention to the long series of negative barometrical deviations in November at Stykkisholm in about the last thirteen years (from 1888), and the corresponding result of positive barometrical deviations at Vienna. From 1868-1878 we had at Vienna an uninterrupted series of negative barometrical deviations in November, whereas at Stykkisholm the pressure was almost certainly very high.

There is also no physical reason for a contrast in the temperature deviation at the centre, and on the right-hand side of a stationary pressure minimum. But as in winter high pressure is usually associated with lower temperature, the result given above agrees well with the preceding result. On the whole, however, there is no great weight to be attached to it.

3. *Dependence of the Temperature Anomaly in North-west Europe on the Pressure Anomaly in Iceland.*—If we examine the negative and positive pressure deviation at Stykkisholm with the simultaneous temperature deviations appearing at the same time in North-west and Central Europe, we get the following result:—

PRESSURE DEVIATION AT STYKKISHOLM.

Negative. Probability of a simultaneous positive temperature deviation in North-west and Central Europe.				Positive. Probability of a negative temperature deviation in North-west and Central Europe.			
Dec.	Jan.	Feb.	Winter.	Dec.	Jan.	Feb.	Winter.
0·90	0·71	0·84	0·82	0·74	0·82	0·64	0·73

These results are conclusive, and confirm the relation between the intensity of the pressure minimum in Iceland and the simultaneous temperature anomalies in North-west and Central Europe, in the first instance for the winter.

A Deepening of the Pressure Minima in Iceland produces a Rise in Winter Temperature in North-west and Central Europe, and vice versâ.—It is outside the object of this paper to examine in any way how far the intensity of the North Atlantic pressure minimum depends on the positive or negative temperature anomaly of the sea-water of the North Atlantic. Such a relation is highly probable, but it would be very difficult to keep cause and effect in this subject asunder.[1] We may draw attention to one circumstance. While the anomaly of sea temperature often lasts for more than a year with the same sign, the pressure anomaly in Iceland changes frequently. The anomalies of sea temperature and of barometrical pressure often differ in sign, sea being +, pressure −.

4. *Anomalies in Rainfall at Stykkisholm and Brussels in Winter.*—Our tables allow of our examining the simultaneous deviations in precipitation at Stykkisholm and Brussels, as to their agreement or the reverse. In the first instance it should be remarked that the result, whatever it may be, cannot be of very great importance, for rainfall is too local a phenomenon, especially in winter.

The enumeration of the deviations of monthly rain at Brussels had 91 times the opposite sign at Stykkisholm. The probability of a deviation in opposite senses at the two stations is therefore 0·68—a rather decisive result, much more so than in the case of temperature.

5. *Comparison of the great Simultaneous Pressure and Temperature Deviations in all Months.*—I have taken all the greater pressure deviations of the months at Stykkisholm and set down beside them the simultaneous temperature deviations at Brussels and Greenwich (mean of the two), and then found the mean value of these corresponding variations.

From October to April inclusive, all the monthly deviations of pressure at Stykkisholm amounting to ·20 in. have been extracted. In May and September those $\geqq$ ·136 in. In June, July, and August those $\geqq$ ·118 in. In summer the deviations of monthly means of ·118 in. are rather rare, even at Stykkisholm.

The following table shows that on the mean, with a probability of 0·74 and a greater positive pressure deviation at Stykkisholm (of about ·272 in.), we

[1] We refer to O. Pettersson, "Ueber die Beziehungen zwischen hydrographischen und meteorologischen Phänomenen," *Met. Zeitschrift*, 1896, and W. Meinardus, "Der Zusammenhang des Winterklimas in Mittel- und Nordwesteuropa mit dem Golfström," *Zeitschrift der Gesellsch. für Erdkunde zu Berlin*, vol. 33. Since that Meinardus has treated this subject again, as have I also in the present paper. As often happens the two of us have independently taken up similar problems. The title of Meinardus' paper is "Ueber Schwankungen der nordatlantischen Zirkulation und ihre Folgen," *Annalen der Hydrographie*, 1904.

can calculate on a negative temperature deviation of 1°·8 Fahr. at Greenwich and Brussels. With a greater probability of 0·84 we can, with a greater negative pressure deviation at Stykkisholm (of ·272 in.), calculate on a positive temperature deviation of 1°·8 at Greenwich and Brussels, or even more. The deeper the barometrical minima in Iceland, the more decided is its action, as might be expected, in the elevation of the temperature in Europe. *The subjoined table is one of the most direct proofs which has been given as yet of the influence of the barometrical depression in Iceland in favour of the climatic improvement of North-west Europe.* If the Icelandic minimum is weakened, this at once shows itself in the depression of temperature in North-western and even Central Europe. As we have seen before, variations of the yearly temperature of more than 3°·6 are the result, if the monthly means of pressure vary ·236 or ·276 in. on one side or other of the mean.

LARGE PRESSURE DEVIATIONS AT STYKKISHOLM AND SIMULTANEOUS TEMPERATURE DEVIATIONS AT GREENWICH AND BRUSSELS.

Month.	Positive Deviation.				Negative Deviation.			
	No. of Cases.	Pressure Deviation at Stykkisholm.	Temperature Deviation at Brussels and Greenwich.	Signs not agreeing with Means.	No. of Cases.	Pressure Deviation at Stykkisholm.	Temperature Deviation at Brussels and Greenwich.	Signs not agreeing with means.
		in.	°			in.	°	
January .	11	+·406	−3·2	2	14	−·311	+2·5	2
February .	12	+·374	−4·1	1	12	−·347	+2·5	2
March . .	10	+·307	−1·1	3	11	−·303	+3·1	0
April . .	10	+·224	−1·3	3	8	−·264	+0·7	2
May . .	7	+·165	−0·4	4	7	−·224	+2·5	1
June . .	9	+·177	−0·4	4	11	−·169	+0·7	3
July . .	9	+·142	−1·3	2	7	−·165	+0·4	3
August . .	10	+·189	−0·5	3	7	−·181	+2·0	0
September .	10	+·221	−1·3	3	10	−·193	+1·3	3
October .	10	+·291	−1·8	2	8	−·291	+0·9	1
November .	14	+·335	−2·5	2	12	−·303	+2·5	1
December .	10	+·350	−3·1	3	15	−·264	+2·7	1
Year . .	122	+·272	−1·8	32	122	−·260	+2·0	19

Naturally the influence of the great barometrical deviations in Iceland on the temperature of North-west Europe is greatest in winter. In summer the mean temperature is much less dependent on the prevailing wind than in winter, and the greater deviations of pressure are more or less frequent. East, North-east, and North winds with bright weather raise the temperature of North-west Europe in summer, so that a weakening of the barometer minimum may even have an influence in raising temperature. This reduction of the climatic influence of the Icelandic depression in summer is quite visible in the table given above. The influence of the seasons is more clearly seen from the following figures:—

	No. of Cases.	Mean Pressure Deviation.	Temperature Deviation Brussels and Greenwich.	Probability.	No. of Cases.	Mean Pressure Deviation.	Temperature Deviation Brussels and Greenwich.	Probability.
		in.	°			in.	°	
Winter half .	67	+·347	−2·7	0·81	72	−·303	−2·4	0·90
Summer half .	55	+·150	−0·9	0·65	50	−·208	−1·2	0·76

In the winter half a large barometer deviation in Iceland with a probability of 0·8 or 0·9 produces a marked temperature deviation in the opposite sense in North-west Europe; in summer the probability of such an effect is less, about 0·7, and the temperature effect much less.

6. *The great Temperature Deviation of the Monthly Means at Greenwich, and the corresponding Pressure Deviation at Stykkisholm.*—It is, naturally, to turn the question round, What were the pressure deviations which held at Stykkisholm at the times of the greatest positive and negative anomalies for months and years at Greenwich (1851 and 1900)? A table, which I have not reproduced here, gives an answer to this question. I have taken out for each month the three greatest positive and negative temperature anomalies, and written opposite to them the corresponding pressure anomalies at Stykkisholm. As was to be expected, the result fully confirmed the former one, when we sought to draw conclusions from the pressure anomalies in Iceland as to the temperature anomalies at Greenwich.

The 42 greatest positive temperature anomalies at Greenwich for 50 years gave, with a probability of 0·83, that we might reckon on a corresponding negative pressure anomaly at Stykkisholm. 41 cases of great negative temperature anomaly at Greenwich coincide with a probability of 0·85 on a simultaneous positive pressure anomaly at Stykkisholm. The mean values are :—

Simultaneous variations of the monthly mean of pressure and temperature at Greenwich and Stykkisholm.

Temperature at Greenwich.	Pressure at Stykkisholm.
°	in.
+4·9	-·117
-5·0	+·185

7. *Corresponding Deviation of the Yearly Means of Pressure at Stykkisholm and of Temperature at Greenwich.*—A small table (not reproduced here) gave these figures. A positive deviation of the yearly mean of pressure at Stykkisholm of ·020 in. and above corresponds with a probability of 0·70, and a negative deviation of the temperature at Greenwich; on the other hand, a negative deviation of the yearly mean of pressure at Stykkisholm of ·020 in. and upwards corresponds in 60 per cent of the cases with a positive deviation of the temperature at Greenwich. The contrast in the deviations comes out much less clearly in the yearly than in the monthly means. This is evidently due to the influence of the summer temperatures, which are less dependent on the Icelandic minimum.

8. *Deviations of the Yearly Mean of Rain from the Average.*—Finally I have given a table to show the relation between the similar rain returns in Brussels and Stykkisholm. It is very instructive, however, to see the contrast between the figures for the first 22 years and the second 22 years.

The years 1857-1878 show almost always the opposite signs of rain-values. The probability of a contrasted anomaly is 0·90. In the second period this figure is only 0·45, and the probability of agreement is greater, 0·55. This shows us how easily short periods of record may lead to error.

In general, as already remarked, we cannot base much on the agreement or opposition of rain at individual stations; we must deal with regional values and, above all, long periods. If we do not do this we may easily be misled, as the table above clearly shows.

Buchan was certainly the first to recognise the relation between the temperature anomalies at Stykkisholm and the temperature anomalies in the British Isles, at a time when the connection between weather and the type of pressure distribution was not yet recognised by meteorologists. In the very interesting paper "On the Cold Weather of March 1867, as illustrating the relation between

Temperature and Pressure of the Atmosphere,"[1] Buchan shows how the cold period of March 1867 was due to the distribution of pressure over Europe at the time, by high pressure over Iceland and North Scotland, and low pressure over the Channel and South-west Europe. From March 11 to 18 the pressure in Iceland was 30·292 ins., in the Faroes 30·162 ins., but over the Bay of Biscay 29·662 ins. The temperature in Scotland was from 9° to 14°·4 below the normal, and it is remarkable that this negative deviation was greatest at the high-level stations, and was greater inland than on the coasts.[2]

With a total change in pressure distribution in the end of March a warm period set in, the pressure became higher in the south than in the north, and the temperature rose above the mean.

The mean deviation of temperature in March 1867 at Edinburgh was only + 3°·2, that of December 1866 on the contrary was − 5°·2, and December 1869 was even colder.[3] February in 1864 and 1865 and the month of March in the same years were nearly as cold.

VARIATIONS OF PRESSURE AT STYKKISHOLM.

	in.			in.
December 1859	+ ·209		February 1864	+ ·012
,, 1860	+ ·319		,, 1865	+ ·228

The following figures for March are specially interesting :—

PRESSURE DEVIATION, STYKKISHOLM.

1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.
− ·374	+ ·224	− ·268	+ ·032	+ ·091	+ ·142	+ ·472	− ·421	+ ·272
+1°·4	−2°·9	+2°·7	−3°·1	−3°·6	−3°·1	−3°·2	+3°·8	−2°·2

The pressure deviation at Stykkisholm was an exact index for a temperature deviation in the opposite sense at Edinburgh. Similar series to these may easily be prepared, and Buchan has been the first to draw attention to the fact.[4]

But there are also exceptions. If, *e.g.*, the pressure in Iceland is low, but the Azores barometer maximum has displaced itself and the barometer is very high over Central or North-west Europe, negative temperatures in Central and North-west Europe may result. The extraordinary cold December of 1879 is an example of this. (A barometer maximum over Central Europe. Radiation cold at Stykkisholm, barometer deviation ·020 in., temperature deviation 3°·1.) The most severe winter in Central Europe, that of 1829-30, had certainly a similar character. The deviation of pressure and temperature at Vienna and Reykjavik were as follows :—

---

[1] *Journal Scottish Meteorological Society*, New Series, vol. **2**, p. 66, August 1867.

[2] In the great cold period of 1860 which Buchan had discussed before (See *Report of Scot. Met. Soc.* for the quarter ending December 1860) the negative deviations were greatest at the low levels, and the temperature at the upper stations was relatively mild. Buchan is right in accounting for this contrast in the two cold periods by the fact that the cold of Christmas 1860 came with calm (radiation cold), while the cold of March 1867 was accompanied by strong North-west and North winds. Broom bushes at Loch Lomond, which were at least thirty years old and had withstood the intense cold of 1860, were killed by the cold winds of March 1867, and so was the heather.

[3] Variations from the mean 1851-1900, Mossman, "The Meteorology of Edinburgh," *Trans. Roy. Soc. Edin.*, vol. **11**, part 3, 1902.

[4] In the later paper on "The Meteorology of Iceland," *Journal*, vol. **2**, p. 287, Buchan carries out this comparison between the pressure anomalies in Iceland and the temperature anomalies in Scotland still further. In July 1868 there was great heat in Scotland, and the pressure at Stykkisholm was very low (deviation − ·102 in.). Also September 1865 was very fine and warm; Stykkisholm had very low pressure (− ·189 in.). In Scotland the barometer was high in both cases.

	Vienna. Deviation. Pressure.	Vienna. Deviation. Temperature.	Reykjavik. Deviation. Pressure.	Reykjavik. Deviation. Temperature.
	in.	°	in.	°
December 1829	+ ·244	− 12·8	− ·138	+ 3·8
January 1830	+ ·051	− 11·3	+ ·110	+ 4·9
February 1830	+ ·063	− 6·7	− ·213	+ 0·5
Winter	+ ·118	− 10·3	− ·079	+ 3·1

What a contrast in temperature between Vienna and Reykjavik in January 1830, Vienna − 14°·9, Reykjavik 2°·0. Similar contrasts are—

January 1833	Vienna − 10°·4	Reykjavik + 15°·3
and reverses,		
December 1833	Vienna + 9°·7	Reykjavik − 6°·3
January 1835	,, + 7·6	,, − 11·5

It is a pity that there are no observations from Iceland for 1840, when Vienna had its coldest winter with − 16°·7.

B. *Relations between the Oscillations of Pressure at Stykkisholm and Ponta Delgada, or between the Two Centres of Action of the Atmosphere of the North Atlantic Ocean.*

A long time ago [1] I drew attention to a remarkable displacement of the two centres of action of the atmosphere at the Azores and Iceland, which took place in January 1881. When the monthly mean of the barometer at Ponta Delgada was 29·508 ins., and that of Stykkisholm 30·190 ins., Stykkisholm had at that time its greatest positive deviation, and Ponta Delgada the greatest negative anomaly of pressure. Since then Meinardus has thrown further light on the displacement of these two centres, reproduced them graphically on charts, and pointed out the relation to the corresponding winter temperature of North-west and Central Europe. This winter was very cold. In contrast to this is the next winter, 1881-2, in regard to pressure as well as temperature.[2] The mean deviation of the pressure was—

	Ponta Delgada.	Stykkisholm.
	in.	in.
Winter 1880-1	− ·205	+ ·469
,, 1881-2	+ ·110	− ·165

Are these contrasts in the deviations to be taken as occasional casual phenomena, or is there any regular alternation in the pressure relations in Iceland and the Azores? Are these two centres of action of the atmosphere in a sort of relation of dependence, at least in regard to the intensity of their development, or is any closer relation between them discoverable?

To answer this question I have taken the simultaneous deviations of the monthly means of pressure at Ponta Delgada (in the period from 1865-90) and compared them with Stykkisholm.[3]

I have next taken all the deviations of the barometer level at Ponta

[1] *Die Vertheilung der Luftdruckes über Mittel- und Südeuropa*, Vienna, 1887.

[2] Meinardus "Das Winterklima von Nordwesteuropa und der Golfstrom," Berlin, *Zeitschrift für Erdkunde*, 33, 1898, with 2 maps. As December 1880 was very warm in Central Europe, one of the warmest of the period 1851-1900, the representation of the late winter (Jan. and Feb. 1881) would have afforded a still more decided picture, at least for the temperature. Hoffmeyer's important paper may also be mentioned in connection with this, although it is well known to meteorologists, *Met. Zeitschrift*, 13, p. 337, and 14, p. 73.

[3] I have brought together the pressure means for Ponta Delgada 1865-85 in the paper quoted above, and have filled up the gaps in the early years by using the records at Angra do Heroismo. The Azores observations begin with 1865, *Met. Zeitschrift*, vol. 7, p. 310. The pressure means 1891-1900 I have received by letter from Mr. Chaves, Director of the Observatory at Ponta Delgada.

Delgada (from the means 1865-90) of ·118 in. and above, and put beside them the corresponding pressure deviations at Stykkisholm, and have then converted the whole to means, so that I obtain the following table :—

RELATIONS BETWEEN THE PRESSURE DEVIATION AT PONTA DELGADA AND STYKKISHOLM.

	Winter.				Summer.		
Number.	Ponta Delgada. in.	Stykkisholm. in.	Probability of contrast.	Number.	Ponta Delgada. in.	Stykkisholm. in.	Probability of contrast.
	Positive Deviations at Ponta Delgada.						
32	+ ·185	− ·106	0·71	10	+ ·142	− ·016	0·70[1]
	Negative deviations at Ponta Delgada.						
28	− ·224	+ ·201	0·82	13	− ·154	+ ·110	0·85

When put together as yearly means.

Number.	No. of opposite signs.	Mean Deviation at Ponta Delgada. in.	Mean Deviation at Stykkisholm. in.	Probability of contrast.
	1. Ponta Delgada + ·118 in. and above.			
42	30	+ ·177	− ·095	0·71
	2. Ponta Delgada − ·118 in. and below.			
41	34	− ·201	+ ·173	0·83

There is therefore a probability of 0·77 in favour of a contrast in the pressure deviations of Ponta Delgada and Stykkisholm.[2] In 83 months there are only 19 with the same sign ; 64 months have opposite signs. If there is a great negative pressure deviation at Ponta Delgada, we can count, with a probability of 0·83, on a positive deviation at Stykkisholm, and, with a somewhat lower probability of 0·71, from a positive deviation at Ponta Delgada, on a negative one at Stykkisholm. It is remarkable that there is no difference between winter and summer in this relation. The contrasts between the pressure deviations at Ponta Delgada and Stykkisholm, which have been exhibited before for the winters 1880-1 and 1881-2, were therefore not isolated phenomena ; they were only extreme cases of phenomena appearing pretty commonly.

We shall now take the question the other way and see what pressure deviations at Ponta Delgada correspond to the greatest positive and negative pressure deviations at Stykkisholm. I have therefore taken from the years 1865-90 the two greatest positive and negative deviations at Stykkisholm, and put beside them the simultaneous pressure deviations at Ponta Delgada. In this way I have obtained this table (abridged here).

RELATIONS BETWEEN THE GREATEST PRESSURE DEVIATIONS AT STYKKISHOLM AND THE SIMULTANEOUS PRESSURE DEVIATIONS AT PONTA DELGADA.

	Winter.			Summer.		
	Stykkisholm. in.	Ponta Delgada. in.	Difference. in.	Stykkisholm. in.	Ponta Delgada. in.	Difference. in.
	Greatest Positive Deviation at Stykkisholm.					
Mean	+ ·461	− ·185	·646	+ ·217	− ·067	·284
	Greatest Negative Deviations at Stykkisholm.					
Mean	− ·374	+ ·126	·500	− ·232	+ ·051	·283

[1] Probability of the opposite sign of the deviation.

[2] I must not omit to mention the paper by H. Hildebrandsson, "Quelques recherches sur les centres d'action de l'atmosphère," *Abhandl. der k. Schwedischen Academie*, vol. 29, p. 5, 1897.

This shows us that the greatest positive pressure deviations at Stykkisholm in 80 per cent of the cases correspond to negative deviations at Ponta Delgada, and the greatest negative pressure deviations at Stykkisholm in 87 per cent of the cases have positive deviations at Ponta Delgada. The probability of a deviation in the opposite sense is 0·83. The result is therefore the same as in the former case, only more decisive.

We may therefore venture to assert that the two centres of action of the atmosphere in the North Atlantic, the pressure maximum near the Azores and the minimum in Iceland, stand in a certain relation to each other ; but we have to note something about this.

If the pressure at the Azores is higher than the average, as happens in more than 70 per cent of the cases, the normal pressure gradient over the Atlantic is increased, the atmospheric machine works more actively, and the climatic advantages of Europe are improved. Conversely, if the Azores anticyclone is reduced, the pressure in Iceland is increased, the normal pressure gradient from south to north may be weakened, or even entirely reversed, and the climatic advantages of North-west Europe are more or less reduced.

From the pressure means in my paper for Ponta Delgada and Stykkisholm, the pressure gradient between Ponta Delgada and Stykkisholm may be easily taken out. The mean, or normal, gradient is seen from the subjoined long-period pressure means.

MEAN PRESSURE AT SEA LEVEL, WITH GRAVITY CORRECTION.

	Ponta Delgada 1866-1900.	Stykkisholm 1851-1900.	Difference.		Ponta Delgada 1866-1900.	Stykkisholm 1851-1900.	Difference.
	in.	in.	in.		in.	in.	in.
January	30·138	29·390	·748	August	30·190	29·808	·382
February	30·103	29·571	·532	September	30·154	29·713	·441
March	30·095	29·733	·362	October	30·091	29·662	·429
April	30·115	29·843	·272	November	30·087	29·764	·323
May	30·134	29·930	·204	December	30·134	29·544	·590
June	30·213	29·831	·382	Year	30·142	29·717	·425
July	30·249	29·804	·445				

In January the pressure difference between the Azores and Iceland reaches its highest maximum, with a lesser one in July, the least gradient to the north comes on in May and again in November. The Azores lie nearly in the centre of the two centres of action. The differences given above accordingly represent the greatest gradient between the sub-tropical pressure maximum and the pressure minimum of the North Atlantic Ocean. Ponta Delgada and Stykkisholm lie nearly under the same meridian, and their difference of latitude is 27°·3.

		Correction of sea-level and 45° lat.
Ponta Delgada	37° 45′ N., 25° 5′ W., 66 ft.	+ ·051 in.
Stykkisholm	65° 4′ N., 22° 7′ W., 37 ft.	+ ·091 in.

The gradient even in January is scarcely ·028 in. (for gravity). The pressure difference between the Azores and Iceland is not unfrequently annulled (Stykkisholm +, Ponta Delgada −).

The results of this for the temperature of Western Europe may be seen from the following figures :—

TRUE PRESSURE AT SEA-LEVEL.

	Dec. 1881.	Jan. 1890.	Feb. 1868.	Feb. 1883.	March. 1868.	March. 1882.
	in.	in.	in.	in.	in.	in.
P. Delgada	30·312	30·237	30·386	30·229	30·390	30·398
Stykkisholm	29·166	29·008	29·201	29·087	29·304	29·304
Difference	+1·146	+1·229	+1·185	+1·142	+1·086	+1·094
Anomaly	+ ·555	+ ·480	+ ·654	+ ·610	+ ·724	+ ·723

TRUE PRESSURE AT SEA-LEVEL.

	Jan. 1867.	Jan. 1881.	Feb. 1895.	March. 1867.	Nov. 1878.	Dec. 1878.
	in.	in.	in.	in.	in.	in.
P. Delgada .	29·831	29·560	29·583	29·701	30·012	29·776
Stykkisholm .	29·926	30·186	30·134	30·197	30·103	30·123
Difference .	- ·095	- ·626	- ·551	- ·496	- ·091	- ·347
Anomaly .	- ·842	-1·374	-1·083	- ·858	- ·413	- ·937

TEMPERATURE DEVIATION.

	Dec. 1881.	Jan. 1890.	Feb. 1868.	Feb. 1883.	March. 1868.	March. 1882.
	°	°	°	°	°	°
Greenwich .	+0·2	+ 4·3	+ 3·4	+3·4	+2·5	+5·2
Brussels .	+0·2	+ 6·1	+ 4·1	+4·3	+3·1	+5·2
Vienna .	+2·2	+ 5·2	+ 6·5	+2·5	+1·1	+9·0
	Jan. 1867.	Jan. 1881.	Feb. 1895.	March. 1867.	Nov. 1878.	Dec. 1878.
	°	°	°	°	°	°
Greenwich .	-4·5	- 7·0	-10·4	-3·8	-3·4	-6·1
Brussels .	-1·6	-10·1	-13·5	-2·9	-2·3	-4·0
Vienna .	+1·6	- 5·6	- 9·7	-1·6	-1·1	-2·5

We cannot, however, always reverse this table; there may be + or − deviations of temperature in Central Europe, without the pressure at Stykkisholm being either low or high: *e.g.* the radiation winter 1879-80 had low pressure in Iceland, but it was also low at Ponta Delgada; there was only a reduction of the normal pressure over the Atlantic, and high pressure over Central Europe. An increased gradient towards the north sweeps West and Central Europe with the warm oceanic West winds. The reverse is the case if this gradient is almost or entirely changed.

The cases in which the pressure at the Azores is increased while that in Iceland is reduced are, theoretically, the most interesting.

If, on the contrary, the pressure at the Azores is lower and that in Iceland is higher, this may be due, and often is so, as in the winter 1880-1, to a displacement of the anticyclone to the north; on which phenomenon no theoretical reasoning can be based.

Otherwise, when the pressure at the Azores is unusually high, this cannot well be considered as a simple displacement of the subtropical anticyclone, but is only a greater intensity of it, owing to increased activity of the atmospheric circulation. If the North-east Trade blows much stronger than usual, it will tend to increase the barometrical maximum on its right. This will increase the atmospheric whirl over the North Atlantic Ocean, and thereby the minimum at its centre will be increased. The increased pressure at the Azores and the deepening of the minimum in Iceland, which is connected therewith, may be related to each other as cause and effect. This imparts more theoretical interest to the circumstance that decided positive deviations at the Azores occur together with negative ones in Iceland. That the probability of this relation only reaches 70-80 per cent, may be attributed to the fact that we can only base the reasoning on the fact of the pressure conditions at two points, so that lateral displacements of the pressure centres may easily produce apparent exceptions. If the pressure minimum in Davis Straits increases itself at the expense of that in Iceland, or if the latter moves towards the North Sea, or if the Azores anticyclone moves towards North Africa or towards Southern or Central Europe (as in December 1879), our two stations alone cannot give us the true gradient. It is only isobaric maps of the Atlantic Ocean which can give us the true key to all the cases. But for that, in order to get

I.—STYKKISHOLM, PRESSURE DEVIATION.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1851	−·469	−·130	−·059	+·154	−·098	+·079	+·114	+·039	+·059	−·083	+·307	−·032	−·010
1852	−·303	+·047	+·287	+·138	−·106	·000	+·008	−·095	+·228	+·213	+·095	−·008	+·042
1853	−·343	+·508	+·079	+·323	+·039	−·024	−·154	+·114	−·134	−·028	−·476	+·382	+·024
1854	−·240	−·150	−·197	−·020	−·138	+·020	+·098	−·102	−·130	−·197	+·063	−·185	−·096
1855	+·547	+·543	−·142	−·177	+·095	−·043	−·032	−·043	−·051	−·028	+·039	+·138	+·071
1856	+·161	+·130	+·295	−·075	+·102	−·142	+·008	+·343	+·075	−·047	+·343	+·165	+·100
1857	+·232	−·528	−·177	+·035	−·039	+·165	−·197	−·059	+·106	−·122	+·075	−·221	−·060
1858	−·130	+·012	+·189	−·016	−·024	−·079	+·079	−·083	−·217	+·091	+·256	−·362	−·023
1859	−·102	−·221	−·051	+·256	−·201	+·181	−·020	−·209	+·028	+·280	+·016	+·209	+·014
1860	−·504	+·024	−·142	−·024	+·118	+·134	+·012	−·071	+·051	−·280	+·370	+·319	+·001
1861	+·075	−·106	−·374	+·177	+·043	+·024	−·201	−·087	+·059	−·177	+·138	+·032	−·033
1862	−·118	+·252	+·224	−·051	−·284	−·217	−·008	−·035	−·047	−·484	−·122	−·240	−·094
1863	−·122	−·378	−·268	−·437	+·075	−·051	+·055	+·091	−·240	−·197	−·205	−·114	−·149
1864	−·232	+·012	+·032	−·083	+·106	−·118	−·118	+·130	−·024	+·386	−·169	+·043	−·003
1865	−·012	+·228	+·091	−·063	−·126	−·024	+·032	+·020	−·189	+·232	−·098	−·228	−·011
1866	−·087	−·047	+·142	+·114	+·055	−·122	+·039	−·028	−·173	−·091	−·067	−·110	−·031
1867	+·480	−·177	+·472	−·098	+·217	+·047	+·134	−·189	−·032	−·173	+·291	+·055	+·086
1868	−·012	−·374	−·421	−·177	−·260	−·232	−·102	−·051	+·264	−·295	+·217	−·221	−·139
1869	−·354	−·299	+·272	−·020	+·201	+·114	+·008	+·142	+·016	+·197	−·032	+·091	+·028
1870	+·075	+·256	+·248	−·177	−·134	+·024	−·051	+·201	−·012	−·095	+·228	+·516	+·090
1871	−·079	+·071	−·209	+·201	+·051	+·205	−·075	−·118	+·213	−·055	+·406	+·012	+·052
1872	−·154	+·012	+·051	+·075	+·016	−·020	+·130	+·181	+·173	−·059	−·087	+·126	+·037
1873	−·264	+·319	−·209	+·217	+·142	−·138	−·008	−·134	+·158	−·118	+·224	−·087	+·009
1874	−·205	−·122	−·071	−·260	+·095	+·118	−·079	−·055	−·098	−·276	−·020	+·347	−·053
1875	+·091	+·276	+·071	+·106	−·366	−·197	+·138	−·012	+·051	−·032	+·374	−·091	+·035
1876	−·098	+·098	−·024	+·236	+·028	−·217	−·232	−·047	+·291	+·032	+·232	+·063	+·031
1877	−·228	−·055	−·008	+·205	+·146	−·047	−·043	+·228	+·224	−·134	−·347	−·228	−·024
1878	+·248	+·028	+·142	+·032	−·122	+·063	−·016	+·106	−·110	+·051	+·429	+·626	+·123
1879	+·272	−·059	−·083	+·051	−·095	−·016	+·083	−·024	−·276	+·098	+·323	−·020	+·022
1880	+·161	−·327	−·004	−·146	+·012	+·071	+·158	−·043	+·039	+·528	−·118	+·358	+·058
1881	+·740	+·311	+·039	+·106	−·032	+·063	−·098	+·032	+·083	+·146	+·425	−·331	+·043
1882	−·102	−·059	−·421	+·213	+·047	+·130	−·142	·000	−·059	−·118	−·114	+·284	−·028
1883	−·217	−·488	+·402	−·185	−·012	+·098	+·126	−·091	+·063	−·280	−·303	−·032	−·076
1884	−·075	−·252	−·260	+·051	−·020	−·071	+·130	−·189	−·118	−·071	+·110	−·280	−·083
1885	+·020	+·165	+·039	−·059	+·102	−·118	−·004	+·272	−·130	+·138	−·055	+·146	+·043
1886	+·189	+·142	+·012	+·020	+·142	−·110	−·028	−·264	+·055	−·098	−·197	+·079	−·005
1887	−·350	−·154	+·106	+·209	−·028	+·071	−·008	+·098	+·154	+·197	+·161	+·260	+·060
1888	+·398	+·138	+·205	+·224	+·091	+·114	+·154	+·063	+·079	+·240	−·327	−·299	+·090
1889	+·035	+·350	+·091	−·028	−·181	−·146	+·205	−·110	+·165	−·024	−·181	−·284	−·012
1890	−·453	+·181	−·276	−·110	−·008	−·020	−·016	−·067	−·126	+·075	−·307	+·142	−·080
1891	+·177	−·236	+·142	+·142	+·095	+·252	+·032	+·020	−·150	−·331	−·032	−·224	−·009
1892	+·091	+·402	+·134	+·075	+·189	+·146	+·051	+·043	−·224	+·295	−·091	+·193	+·109
1893	+·437	+·150	−·142	−·071	−·055	+·032	+·059	+·087	−·012	−·028	+·264	−·280	+·012
1894	−·102	−·587	−·390	−·158	+·138	−·224	·000	+·012	+·331	+·154	−·445	−·024	−·107
1895	+·437	+·559	−·118	−·024	−·087	+·067	−·047	+·032	−·134	+·158	−·189	−·004	+·054
1896	+·276	−·256	−·291	−·158	−·032	+·039	−·118	+·126	+·012	+·350	−·043	−·272	−·030
1897	+·413	−·134	−·130	−·398	−·067	+·252	−·032	−·098	+·051	+·067	+·079	−·098	−·007
1898	−·197	−·193	+·083	−·311	+·032	−·020	+·043	−·165	−·095	−·047	−·232	−·217	−·109
1899	+·122	−·051	+·205	+·098	+·126	−·028	−·106	+·134	−·039	−·067	−·193	+·102	+·026
1900	−·165	+·480	+·445	−·079	−·008	+·071	+·059	+·020	−·173	+·071	−·197	−·284	+·020
Mean	·228	·222	·179	·137	·100	·100	·078	·100	·120	·161	·202	·189	·051

II.—Ponta Delgada, Pressure Deviation.

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1865	-·138	-·087	+·110	-·032	-·067	+·004	+·071	+·150	+·059	-·024	-·087	-·020	-·008
1866	+·004	+·138	+·028	-·134	-·083	+·004	+·028	+·012	+·095	-·024	-·043	-·020	·000
1867	-·311	+·087	-·398	+·150	-·158	+·051	·000	+·043	+·075	+·161	-·205	+·016	-·039
1868	+·071	+·284	+·287	+·095	+·051	+·079	-·016	+·087	-·055	+·228	-·055	-·146	+·075
1869	-·075	+·240	+·236	-·012	-·071	-·067	+·004	+·055	-·004	+·008	+·193	+·043	+·047
1870	+·079	-·335	-·134	+·012	+·074	+·039	+·016	-·067	+·012	+·083	-·071	-·110	-·032
1871	+·244	-·024	+·016	-·118	-·063	+·059	+·016	-·032	-·035	+·028	-·091	+·146	+·012
1872	+·043	-·142	-·130	+·012	+·114	+·004	-·043	-·012	-·032	+·181	+·055	·000	+·004
1873	+·024	+·067	+·067	-·189	+·035	+·059	+·004	+·134	-·063	+·150	-·047	+·020	+·024
1874	+·091	+·055	+·098	+·047	-·024	+·079	+·008	+·047	+·059	+·075	+·012	+·201	+·063
1875	-·102	-·008	-·071	-·095	+·004	+·114	+·028	-·075	-·067	+·043	-·110	-·134	-·039
1876	+·043	-·067	+·079	+·126	+·118	+·110	-·008	+·024	-·098	-·134	-·339	-·240	-·032
1877	-·028	+·165	+·016	-·173	-·106	-·035	+·067	-·169	-·098	-·028	+·110	+·197	-·008
1878	+·189	-·032	+·150	-·252	-·110	-·043	+·032	-·122	+·032	-·067	-·079	-·362	-·055
1879	-·024	+·110	+·154	+·047	+·110	-·102	+·039	-·024	+·079	+·071	-·228	-·169	+·004
1880	-·193	-·039	-·039	+·075	-·008	+·035	-·091	-·020	-·043	-·307	+·098	-·075	-·051
1881	-·583	+·024	-·335	-·110	+·087	+·051	+·059	-·004	-·102	+·035	-·024	+·169	-·059
1882	+·079	+·059	+·295	+·039	-·043	+·087	+·039	+·075	+·098	+·008	+·177	-·020	+·075
1883	-·043	+·122	-·091	+·047	+·134	-·098	-·047	+·055	·000	+·146	+·098	+·079	+·035
1884	+·032	-·028	+·032	-·154	+·047	+·024	-·071	-·032	+·051	+·150	-·020	+·110	+·012
1885	-·087	-·236	+·181	+·118	-·035	+·047	+·032	-·106	+·083	+·095	-·126	-·087	-·008
1886	+·130	+·059	-·126	-·087	+·020	-·008	+·039	+·059	-·039	+·063	+·126	+·016	+·020
1887	+·035	+·087	-·221	-·181	+·059	-·095	·000	-·051	+·047	-·177	+·008	-·205	-·059
1888	-·051	-·087	-·083	+·098	-·032	-·043	+·004	+·043	-·154	-·134	+·122	+·016	-·024
1889	+·189	+·260	+·051	+·205	-·035	+·039	-·035	+·059	+·012	+·138	+·146	+·244	+·106
1890	+·091	-·012	+·142	+·150	-·020	+·110	+·083	+·059	+·043	+·095	+·201	-·028	+·075
1891	+·110	·000	-·079	-·051	+·028	-·130	-·106	+·055	+·051	-·024	+·035	+·091	·000
1892	+·102	-·079	-·126	+·016	-·032	-·024	+·043	+·047	+·051	-·106	+·083	-·063	-·008
1893	-·130	-·047	-·154	-·039	-·098	-·158	+·059	-·091	+·126	+·075	-·071	+·142	-·024
1894	+·016	+·193	+·004	+·095	+·024	+·039	+·039	+·020	-·134	-·209	+·055	+·083	+·020
1895	-·043	-·520	+·075	-·091	+·004	-·004	-·043	-·016	-·091	-·177	-·134	-·043	-·091
1896	-·008	·000	+·213	+·173	+·087	-·039	+·039	+·071	+·028	-·035	-·091	+·106	+·047
1897	-·024	+·118	+·079	+·122	-·020	-·051	-·091	+·020	+·071	-·161	+·028	+·039	+·012
1898	+·067	+·095	-·020	+·035	-·059	-·142	-·079	-.039	-·130	-·098	+·012	-·028	-·032
1899	-·161	-·323	-·193	+·043	-·028	+·067	+·028	-·083	+·055	-·228	·000	-·032	-·071
1900	+·181	-·244	-·028	+·043	+·059	-·028	-·043	+·039	+·047	+·028	+·189	+·020	+·024
Mean	·105	·124	·126	·098	·059	·062	·039	·056	·065	·107	·100	·100	·037

a view of 50 years, we should want at least 600 monthly maps, and it will be a good twenty years before the "Hoffmeyer charts" have reached that age. These charts will at some time or other afford splendid material for the investigation of this question on all sides. But still the difference of pressure between our two stations Ponta Delgada and Stykkisholm will afford us in most cases the most convenient and shortest expression for the gradient over the North Atlantic Ocean.

The Meteorological Office.

On March 31, the last day of their official existence, the Meteorological Council gave an "At Home" in 63 Victoria Street. The various rooms of the Meteorological Office were open for inspection, and in them was arranged an interesting collection of charts, diagrams, and instruments. These exhibits were intended to illustrate the character of the work done in the Office from the time of its commencement under Admiral FitzRoy to the present day. The visitors had an opportunity of seeing a Weather Map prepared from synchronous observations specially made at 4 p.m.

Rainfall of the Ben Nevis Observatories.

In the *Journal of the Scottish Meteorological Society* just issued, Mr. A. Watt has a paper on "The Rainfall of the Ben Nevis Observatories," in which he deals with the rainfall at the summit (4405 ft.) and at the Fort William Observatory (31 ft.). At the high-level station the rainfall was measured every hour, and at the low-level observatory the record was taken from the Beckley self-recording rain-gauge.

The average monthly rainfall for the 13 years 1891-1903 was as follows:—

	Ben Nevis. ins.	Fort William. ins.
January	19·02	8·68
February	15·08	6·87
March	16·79	7·01
April	9·64	3·97
May	8·33	3·48
June	7·76	3·48
July	11·30	4·64
August	14·00	6·89
September	16·86	8·20
October	14·81	7·92
November	15·95	7·50
December	21·23	11·32
Year	170·77	79·96

It will be seen from the above that the rainfall on the summit of Ben Nevis approximates very closely to that at the Stye, Cumberland.

The following figures, which give the average weight of each two-hourly fall, show the mean rainfall intensity for the 11 years 1891-1901:—

	A.M.						P.M.					
	0-2 in.	2-4 in.	4-6 in.	6-8 in.	8-10 in.	10-12 in.	12-2 in.	2-4 in.	4-6 in.	6-8 in.	8-10 in.	10-12 in.
Ben Nevis	·099	·102	·098	·100	·104	·105	·110	·106	·108	·102	·102	·099
Fort William	·065	·065	·062	·062	·060	·080	·078	·074	·068	·067	·067	·065

As regards Ben Nevis, there is an early morning minimum of intensity and an early afternoon maximum. At Fort William the intensity minimum falls most frequently from 8-10 a.m., or slightly later than that on Ben Nevis, whilst the maximum falls about noon. Speaking very generally, it appears that at the foot of the mountain rain falls more frequently, but less heavily, by night than by day; whilst on the summit the variations are less pronounced, though they are on the whole in sympathy with those at Fort William.

National Physical Laboratory, Kew Observatory, Richmond, Surrey.

Meteorological Observations.—The several self-recording instruments for the continuous registration of atmospheric pressure, temperature of air and wet-bulb, wind (direction, pressure, and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records have been duly registered. The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

Earth Thermometers.—The two Symons' earth thermometers on the lawn, one at a depth of 1 ft. and the other at a depth of 4 ft., have been read at 10 a.m., 4 p.m., and 10 p.m. daily throughout the year, and the 10 a.m. readings have been forwarded weekly to the Meteorological Office, together

with the corresponding readings of the solar radiation and terrestrial radiation thermometers.

A number of observations were made with the Symons' pattern earth thermometers on the lawn, and others of similar type, with a view to ascertaining how the readings are likely to be affected under normal conditions by the changes of temperature to which these instruments are exposed during the time required to haul them up and read them.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Cloud Observations.—On the initiative of the Meteorological Office, special cloud observations have been made with the Fineman nephoscope in connection with the International scheme of balloon ascents.

Electrograph.—This instrument worked generally in a satisfactory manner during the year.

A series of curves—ten a month—have been selected as representative of the variations of potential on electrically "quiet" days, defined as days when irregular fluctuations of potential are fewer than usual. These curves have been tabulated, and the results appear, with the permission of the Meteorological Office, in the Annual Report.

Similar curves have also been selected and tabulated on corresponding lines for the years 1899, 1900, and 1901, and there are now six years' tabulations and results available for discussion, which it is hoped may be proceeded with during 1905.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the Observatory lawn, referred to in previous Reports, have been continued, and the observations have been taken every day when possible, excluding Sundays and wet days. The ratios of the "curve" and the "fixed station" readings have been computed for each observation, and these throw considerable light upon the action of the self-recording electrometer, especially with reference to the insulation problem.

Seismological Observations.—Prof. Milne's "unfelt tremor" pattern of seismograph has been maintained in regular operation throughout the year. The largest disturbance took place on April 4, when the maximum amplitude exceeded 17 mm.

The mean temperature for the year was 49°·8, which is 0°·5 higher than the average for the 30 years 1871-1900.

The following table gives the differences of the mean monthly temperatures from the corresponding mean values for the 30 years 1871-1900:—

Month.	Difference from 30 years mean.	Month.	Difference from 30 years mean.
January	+1°·1	July	+2°·9
February	0·0	August	0·0
March	−1·3	September	−1·7
April	+2·4	October	+2·0
May	+1·4	November	−1·9
June	−1·1	December	+1·5

The maximum temperature in the shade was 86°·4 on August 4, and the minimum was 24°·1 on November 26.

The mean height of the barometer was 30·010 ins., which is 0·047 in. higher than the average for the 30 years 1871-1900.

The extremes ranged from 30·752 ins. on January 22 to 28·642 ins. on February 9.

The maximum temperature in the sun's rays (black-bulb *in vacuo*) was 142° on July 15 and August 3, and the lowest temperature on the grass was 13° recorded on December 9.

The mean percentage of bright sunshine was 31 (old style) and 34 (new style) (see *Quart. Journ. Roy. Met. Soc.* vol. **28**, p. 209), being 1 per cent above the average for the 25 years 1877-1901.

The rainfall amounted to 21·20 ins., being 2·66 ins. below the average for 40 years.

In marked contrast to the preceding year, there was no daily fall of an inch and over, the largest total being 0·94 in. on August 31.—CHARLES CHREE, Superintendent of Observatory Department.

Royal Observatory, Greenwich.

The meteorological observations by eye and by self-recording instruments, have been maintained as usual during the year 1904, and the special observations of clouds on selected days in each month have been continued at the request of the International Balloon Committee, a Fineman nephoscope having been used for this purpose since its arrival in April.

Daily reports have been issued as in previous years, weekly meteorological returns furnished to the Registrar-General, monthly returns of temperature and sunshine to the Royal Meteorological Society, and quarterly reports to the Meteorological Office.

The temperature of the air ranged between 91°·0 on August 4 and 23°·2 on November 26, this being the third time in 64 years with the minimum for the year in November. The mean temperature for the year was 49°·8, being 0°·3 above the average. The mean temperature for July was 3°·0 above the average for July, and for September 1°·8 below the average for September, these being the greatest departures from the monthly averages. The sunshine recorded in the year amounted to 1459 hours out of a possible duration of 4466 hours, giving a percentage of nearly 33 for the year. There were 90 sunless days. The total amount of sunshine was 78 hours greater than the average value for the years 1887 to 1904, excluding the years 1894 to 1896, when the sunshine ball was proved to have been defective. The longest register for a single day was 14·6 hours on July 6, but the highest percentage of possible sunshine was 93 on August 3, 90 per cent being also reached on two other days in August and three in September. The highest reading of the solar radiation thermometer with blackened bulb *in vacuo* was 152°·2 on August 3, and the lowest readings on the grass were 14°·6 on January 1, 14°·9 on December 21, and 15°·6 on March 17.

During August a comparison was made between simultaneous readings of two similar solar maximum radiation thermometers, the result of which tended to show that too much reliance should not be placed upon single readings, as, although the mean results for the two instruments were within about ⅓ of a degree (the scale corrections being unknown), yet individual discordances showed a range of about 16°.

Rain fell on 153 days in the year to the total amount of 20·663 ins., being 3·875 ins. less than the average for the 50 years 1841-1890, the monthly falls being below the corresponding monthly average in all but the three winter months, January, February, and December. Most of the rain measured in July fell during a few hours on the evening of the 25th, when the rate of fall for about 13 minutes reached the high average of 3 ins. per hour.

The greatest recorded pressure of the wind was 24 lbs. on February 13. The greatest daily velocity was 867 miles on November 9, and the least 49 miles on December 22. The greatest hourly velocity was 45 miles on December 30. The total movement for the year was 99,838 miles, the

monthly amounts being greatest in February and April, and least in September and October.

Observations of parhelia were made on five occasions during the year and of paraselenæ on three occasions.—W. H. M. CHRISTIE, *Astronomer-Royal.*

Royal Observatory, Edinburgh.

The meteorological observations during 1904 have been carried on by the staff of the observatory as in former years, and no changes or additions to the instruments in use have been made, except the substitution of a new pair of shade maximum and minimum thermometers by Apps for the pair previously in use. Monthly copies of all the readings and estimates have been supplied to the Secretary of the Scottish Meteorological Society, and the means have been printed in the Quarterly Reports of the Registrar-General for Scotland, along with similar returns from a large number of other stations in Scotland. Weekly returns of temperature and rainfall have also been furnished to the Registrar-General. At the request of the Editor of the *Scotsman* newspaper, a summary of the meteorological conditions of each week is regularly forwarded to him for publication. It includes, as well as a summary of wind velocities, sunshine, and rainfall, a complete set of readings of the barometer, dry and wet bulb thermometers, and the shade and exposed thermometers, with notes on the weather of each day. A summary of the mean values for each month and for the year is also published.

The mean height of the barometer for the year, reduced to 32° and sea-level, was 29·890 ins., which exceeds the average of the past nine years by only ·002 in. The highest reading during the year was 30·690 ins. on January 21, and the lowest 28·558 ins. on February 13.

The mean temperature of the year was 46°·4, exactly the same as that of the preceding year, or 0°·4 less than the average. The temperature was below the average in February by 2°·0, in March by 1°·4, in June by 1°·2, and in November by 1°·5 ; and above the average in April by 1°·1 and in October by 1°·0. In the other month it differed from the average by not more than half a degree. The maximum temperature shown by the exposed black bulb thermometer was 136°·8 on August 6, and the maximum in shade 75°·2 on August 4. The minimum on grass was 14°·0 on December 11, and in shade 21°·4 on February 29.

The total number of hours of bright sunshine recorded by the Campbell-Stokes instrument throughout the year was 1310·7, or 29·3 per cent of the possible duration, compared with 1342·3 hours, the average of the past four years, or 30·0 per cent of the possible. June, with 175·2 hours, was the month with the greatest number of hours of sunshine, while August showed 150·6, and July 149·7. January and December had the smallest number of hours, 37·0 and 37·9 respectively. The highest percentage of possible duration was 38·8 in October, and the lowest 15·7 in January.

The total rainfall for the year was 24·03 ins., or 0·56 in. less than the average of the past nine years, while rain fell on 168 days, or 34 less than the average. The wettest month was August, when 4·30 ins. were measured, the 17th contributing 1·15 ins. to this amount. This was the only day in the year in which the precipitation reached 1 inch within the 24 hours. The driest month was October, when only 0·54 in. fell.

The total number of miles of wind registered by the Robinson anemometer was 156,734, or an excess of 9277 above the average of the past seven years. The maximum velocity in any single hour was 71 miles on January 6. The stormiest day was April 10, when 1054 miles passed the instrument, and the calmest June 3, when only 91 miles were recorded.

The weekly readings of the deep rock thermometers on the Calton Hill

have been continued, and the King's barograph has been in constant operation throughout the year.—R. COPELAND, *Astronomer-Royal for Scotland.*

RECENT PUBLICATIONS.

Annali dell' Ufficio Centrale Meteorologico e Geodinamico Italiano. Serie Seconda. Vols. **14**, Part 3, 1892; **20**, Part 1, 1898; **21**, Part 1, 1899; and **22**, Part 1, 1900. Rome, 1904. 4to.

There has been considerable delay in the publication of these volumes. The parts for 1898 to 1900 are devoted to the observations of thunderstorms in Italy, which are given in full and are discussed by V. Monti and by A. Pochettino.

Annals of the Astronomical Observatory of Harvard College. EDWARD C. PICKERING, Director. Vol. **58**. Part I. *Observations and Investigations made at the Blue Hill Meteorological Observatory, Massachusetts, U.S.A.*, under the direction of A. LAWRENCE ROTCH. Cambridge, 1904. 4to. 62 pp.

This contains a paper by Mr. H. H. Clayton on "The Diurnal and Annual Periods of Temperature, Humidity, and Wind-Velocity up to four kilometres in the Free Air and the Average Vertical Gradients of these Elements at Blue Hill." In this paper the author gives the results from the kite observations which have been made for several years past at Blue Hill Observatory. The diurnal period in relative humidity is the inverse of that of the temperature at all levels up to and including 4920 ft. (1500 metres). Near sea-level the mean temperature is lowest in January, and highest in July. At higher levels, the lowest temperature is found in January, up to the highest point reached by the kites; but the maximum temperature of the year is displaced from July to August at a height of about 4920 ft., and above this level the maximum is found in August at each successive 1640 ft. (500 metres) up to the highest point reached. The wind-velocity near the ground attains a maximum in March and a minimum in August. The March maximum disappears at a very small height, not much exceeding 656 ft. (200 metres), and is replaced at higher levels by a maximum in January and February. The time of minimum wind-velocity tends to occur earlier in the year with increasing height above the ground, and is found in June at a height of 9840 to 11,480 ft. (3000-3500 metres).

The author sometimes gives the temperatures in Fahrenheit and sometimes in Centigrade, while the heights are given in metres. It would have been much more convenient for British readers if all the values had been expressed in English measures.

Aus dem Archiv der Deutschen Seewarte. **27**. 1904. Hamburg, 1904. 84 pp. and 3 pl.

This volume contains the following papers:—"Versuche über den Stau und Sog an den Oberflächen halbeingetauchter, schrag durch das Wasser geführter, drachenähnlicher Körper," von Prof. Dr. W. Köppen (10 pp. and pl.).—"Barometer und Wetter," von Prof. Dr. W. J. van Bebber (17 pp.).—"Der tägliche Gang der erdmagnetischen Elemente in Kengua Fjord," von Dr. L. Steiner, (11 pp. and pl.).—"Die tägliche Luftbewegung über Hamburg in den einzelnen Monaten des Jahres" (44 pp. and pl.).

Jelinek's Anleitung zur Ausführung meteorologischer Beobachtungen nebst einer Sammlung von Hilfstafeln. In zwei Teilen. Fünfte umgearbeitete Auflage. Herausgegeben von der Direktion der k.k. Zentralanstalt für Meteorologie und Geodynamik. Erster Teil. Wien, 1905. 8vo. 9 + 124 pp.

This part contains the Instructions for taking Meteorological Observations at Stations of the First to Fourth Orders. The work has been revised and brought up to date. It has copious illustrations of instruments, and also con tains four plates showing cloud forms.

Lehrbuch der Meteorologie. Von Dr. JULIUS HANN. Zweite, umgearbeitete Auflage. Leiferung 1-2. Leipzig, 1905. Chr. Herm. Tauchnitz. 8vo.

These two numbers form the first part of a new edition of Dr. Hann's valuable text-book on Meteorology. This second edition is to be issued in about six parts. A notice of the first edition (1901) was given in the *Quarterly Journal,* vol 27, pp. 163-4, 310-1.

We shall reserve notice of this new work until all the parts have been published.

Les Bases de la Météorologie Dynamique. Historique-État de nos connaissances. Par M. le Dr. H. HILDEBRAND HILDEBRANDSSON et M. LÉON TEISSERENC DE BORT. 7me Livraison. Paris, 1904. 8vo. 66 pp. and 21 pl.

This Seventh Part is devoted to two chapters, viz. 5 and 6. These deal respectively with Thunderstorms and Hail, and Whirlwinds and Tornadoes.

Observatoire St. Louis, Jersey (Iles de la Manche), Angleterre. Bulletin des Observations Magnétiques et Météorologiques. XI^e Année, 1904. Jersey, St. Hélier, 1904-5. 4to.

The observations at this observatory are carried on under the direction of the Rev. Marc Dechevrens, S.J. Hourly results of several elements are given for 1904, and also the means for the 10 years 1894-1903.

Results of the Magnetical and Meteorological Observations made at the Royal Observatory, Greenwich, in the year 1902 : *under the direction of* W. H. M. CHRISTIE, C.B., F.R.S., Astronomer-Royal. Edinburgh, 1904. 4to. 57 + 121 pp.

This volume is on the same lines as the preceding ones. The whole of the work of the Magnetical and Meteorological Department was under the superintendence of Mr. W. C. Nash, and routine observations were in general made by the staff of computers.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of general interest.

For a full Bibliography the reader is referred to the *International Catalogue of Scientific Literature.*

Abbe, C.—The Introduction of Meteorology into the Courses of Instruction in Mathematics and Physics. *Monthly Weather Rev., Washington,* **32**, 1904 (513-515; 560-561).

Alciatore, H. F.—A simple, effective, and inexpensive Lightning Recorder. *Monthly Weather Rev., Washington,* **32**, 1904 (511-513).

Anderkó, A. v.—Ein neuer Ombrograph. *Meteor. Zeits., Vienna,* **21**, 1904 (518-521).

Arendt, T.—Über die Gewitterverhältnisse von Berlin und dessen Umgebung. *Wetter, Berlin,* **21**, 1904 (265-274), **22**, 1905 (9-17).

Arvanitakis, G.—Mémoire sur une nouvelle méthode pour mesurer la hauteur des nuages. *Bull. Soc. Khédiviale de Géog., Cairo,* **6**, 1904 (313-323 and pl.).

Assmann, J.—Niederschläge in Lüdenscheid. *Wetter, Berlin,* **21**, 1904 (283-284).

Assmann, R.—Das Aeronautische Observatorium bei Berlin im Jahre 1904. *Wetter, Berlin,* **22**, 1905 (19-20).

Bebber, W. J. van.—Bemerkenswerte Stürme, II. Sturm vom 8 und 9 November 1904. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (559-562 and pl.), **33**, 1905 (49-55 and pl.).

Bentley, W. A.—Studies of Raindrops and Raindrop Phenomena. *Monthly Weather Rev., Washington,* **32**, 1904 (450-456).

Bily, J.—Thunderstorms at Tampa, Fla. *Monthly Weather Rev., Washington,* **32**, 1904 (457-461).

Bonacina, L. C. W.—The great Problem of Meteorology. *Symons' Met. Mag., London,* **40**, 1905 (7-10).

Chree, C.—An Analysis of the Results from the Falmouth Magnetograms on "Quiet" Days during the Twelve Years 1891-1902 (Abstract). *Proc. Roy. Soc., London,* **74**, 1904-5 (323-326).

Cordeiro, F. J. B.—Vortex Rings as Revolving Solids. *Monthly Weather Rev., Washington,* **32**, 1904 (415-416).

Cortie, A. L.—Magnetic Storms and Associated Sun-spots. *Monthly Notices, R. Astr. Soc., London,* **65**, 1904-5 (197-205).

Davis, T. H.—The Advancement of Meteorology. *Monthly Weather Rev., Washington,* **32**, 1904 (456-457).

Dines, W. H.—On Kites, Kite-flying, and Aëroplanes. *Aëronautical J., London,* **9**, 1905 (4-7).

Ditte, A.—Les métaux dans l'atmosphère. *Ciel et Terre, Brussels,* **25**, 1904-5 (497-510, 525-534).

Elsner, G. v.—Die Niederschlagsverhältnisse der "Görlitzer Heide" und ihrer Umgebung. *Meteor. Zeits., Vienna,* **21**, 1904 (510-514 and pl.).

Evans, J. W.—Hydrography of the Andes. *Geog. J., London,* **25**, 1905 (66-70).

Fényi, J.—Meteorologische Beobachtungen in Zumbo am Zambesi, Südafrika. *Meteor. Zeits., Vienna,* **21**, 1904 (524-526).

Gallenkamp, W.—Über den Verlauf des Regens (Eine neue Methode der Regenmessung). *Meteor. Zeits., Vienna,* **22**, 1905 (1-10 and pl.).

Gradenwitz, A.—The Conical Wind Motor. *Elect. Rev., London,* **55**, 1904 (973-974).

Hall, A. D.—Autumn Rainfall and the Yield of Wheat. *The Times, London, Feb.* 9, 1905.

Hamberg, H. E.—Vieljährige Temperaturmittel für Schweden. *Meteor. Zeits., Vienna,* **21**, 1904 (521-523).

Hammer, D.—Airy's Theory of the Rainbow. *Monthly Weather Rev., Washington,* **32**, 1904 (503-511).

Hann, J.—Klimatabellen für Kamerun. *Meteor. Zeits., Vienna,* **21**, 1904 (541-547).

Hann, J.—Einige Ergebnisse der meteorologischen Beobachtungen auf Franz Josefs-Land Zwischen 1872 und 1900. *Meteor. Zeits., Vienna,* **21**, 1904 (547-555).

Hann, J.—Klima von Innichen, Pustertal, Tirol. *Meteor. Zeits., Vienna,* **21**, 1904 (565-569).

Heidke, P.—Einfluss des Windes auf die Fahrt von Dampfern. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **33**, 1904 (17-28).

Hergesell, M. H.—The Work of the International Commission for Scientific Aëronautics. Translated by Helen A. Bruce. *Aëronautical J., London,* **9**, 1905 (7-12).

Hutchins, D. E.—Indian and South African Rainfalls, 1892-1902. *Nature, London,* **71**, 1904-5 (342-344).

K[nipping], E.—Der Taifun vom 20 August 1904 bei Quelpart. *Ann. d. Hydrog. u. Marit. Met., Berlin,* **32**, 1904 (583-586).

Lockyer, W. J. S.—Cosmical Physics [in 1904]. *The Science Year Book,* **1905**, *London,* 1905 (93-94).

London Fogs. *The Times, London, Nov.* 29, 1904.

Lüdeling, G.—Luftelektrische und Staub-Messungen an der Ostsee. *Erg. d. Meteor. Beob. in Potsdam,* **1901**, *Berlin,* 1904 (5-22).

Lüdeling, G.—Luftelektrische und Staub-Messungen auf Helgoland. *Erg. d. Meteor. Beob. in Potsdam,* **1901**, *Berlin,* 1904 (23-25).

Maillet, E.—Sur certains phénomenes hydrauliques et, en particulier celui de Maitrot de Varennes. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (225-229).

Maillet, E.—Sur la durée de propagation des maxima des crues dans le bassin de la Seine. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (229-233).

Maillet, E.—Résumé des observations centralisées par le service hydrométrique du Bassin de la Seine pendant l'année, 1903. *Ann. Soc. Mét. France, Paris,* **52**, 1904 (249-261).

Marriott, W.—Meteorology in 1904. *The Science Year Book,* **1905**, *London,* 1905 (113-115).

Maunder, E. W.—Magnetic Disturbances, 1882 to 1903, as recorded at the Royal Observatory, Greenwich, and their association with Sun-spots. *Mon. Not. R. Astr. Soc., London,* **65**, 1904 (2-34 and pl.).

Maurer, J.—Experimentelle Untersuchungen über das Verhalten des Trägheitskoeffizienten der ventilierten Thermometer unter variablem Druck des aspirierenden Mediums. *Meteor. Zeits., Vienna,* **21**, 1904 (489-502).

Mill, H. R.—England and Wales viewed geographically. *Geog. J., London,* **24**, 1904 (621-636 and map.)

[Mill, H. R.]—The Frost and Snow of November 1904. *Symons' Met. Mag., London,* **39**, 1904 (201-203).

[Mill, H. R.]—The Rainfall of 1904 [in the British Isles]. *Symons' Met. Mag., London,* **39**, 1904 (221-222, 243).

[Mill, H. R.]—The High Barometer of January 1905. *Symons' Met. Mag., London,* **40**, 1905 (2-4).

Moureaux, T.—Résumé de trente années d'observations météorologiques à l'observatoire du Parc Saint-Maur, 1874-1903. *Ann. Soc. Mét., France,* **52**, 1904 (233-242) **53**, 1905, (9-16, 58-61).

Murray, Sir J., and Pullar, L.—Bathymetrical Survey of the Fresh-water Lochs of Scotland. *Scot. Geog. Mag., Edinburgh,* **20**, 1904 (628-640).

Nordmann, C.—The Sun-spot Period and the Variations of the Mean Annual Temperature of the Earth. *Smithsonian Report,* **1903**, *Washington,* 1904 (139-149).

Okada, T.—On the Duration of Rainfall. *J. Met. Soc. Japan, Tokio,* **23**, 1904, No. 11.

Perlewitz, P.—Drachenaufstiege in ihrem Einfluss auf Gewitter. *Wetter, Berlin,* **21**, 1904 (248-255).

Pernter, J. M.—Methods of forecasting the Weather. *Smithsonian Report*, **1903**, *Washington*, 1904 (151-165).

Pic du Midi Observatory. *Nature, London*, **71**, 1904-5 (354-355).

Pirie, J. H. Harvey.—The Scottish National Antarctic Expedition. Summer Work in the South Orkneys. *Scot. Geog. Mag., Edinburgh*, **21**, 1905 (34-37).

Plehn, Dr. und Hutter.—Das Klima von Kamerun. *Meteor. Zeits., Vienna*, **21**, 1904 (537-541).

Primrose, Sir J. U.—The Smoke Problem. *J. R. Sanit. Inst., London*, **25**, 1904 (668-679).

Proctor, F. W.—A New Theory of Fog Formation. *Monthly Weather Rev., Washington*, **32**, 1904 (406-410).

Quervain, A.—Bericht über die iv. Konferenz der internationalen Kommission für Wissenschaftliche Luftschiffahrt in St. Petersburg. *Meteor. Zeits., Vienna*, **22**, 1905 (22-26).

Resultate der meteorologischen Beobachtungen auf dem Ben Nevis in den Jahren 1901 und 1902. *Meteor. Zeits., Vienna*, **21**, 1904 (569-570).

Rona, S.—Uber die heurige Dürre in Ungarn. *Meteor. Zeits., Vienna*, **21**, 1904 (560-564).

Sapper, K.—Meteorologische Beobachtungen, angestellt in der Republik Guatemala in den Jahren 1902 und 1903. *Meteor. Zeits., Vienna*, **21**, 1904 (578-581).

Schuster, A.—Sun-spots and Magnetic Storms. *Monthly Notices, R. Astr. Soc., London*, **65**, 1904-5, 186-197.

September [1904]. Floods in the South-west. *Monthly Weather Rev., Washington*, **32**, 1904 (465-468).

Shaw, W. N.—Autumn Rainfall and Yield of Wheat. *The Times, London, Feb.* **7**, 1905, and *Symons' Met. Mag., London*, **40**, 1905 (10-12).

Sieberg, A.—Erdbeben und Witterung-Eine Studie über tellurische Dynamik. *Wetter, Berlin*, **22**, 1905 (1-9).

Skottsberg, C.—On the Zonal Distribution of South Atlantic and Antarctic Vegetation. *Geog. J., London*, **24**, 1904 (655-663 and map 117-126).

Smith, W. G.—Botanical Survey of Scotland. *Scot. Geog. Mag., Edinburgh*, **20**, 1904 (617-628).

Smith, W. G.—Botanical Survey of Scotland, III. and IV.—Forfar and Fife. *Scot. Geog. Mag., Edinburgh*, **21**, 1905 (4-23 and map, 57-83 and map, 117-126).

Spencer, J. H.—Three Notable Meteorological Exhibits at the World's Fair. *Monthly Weather Rev., Washington*, **32**, 1904 (411-412).

Sprot, J.—The Tallest Anemometer Post. *Symons' Met. Mag., London*, **39**, 1904 (204-206).

Symons, H. B.—A Note on Naples. *Baln. Clim. J., London*, **9**, 1905 (28-32).

Szalay, L. von.—Über die Empfindlichkeit der Gewitterapparate. *Meteor. Zeits., Vienna*, **22**, 1905 (10-22 and pl.).

Tamura, S.—Mount Tsukuba Meteorological Observatory. What does Meteorology need for its Future Advancement? *Monthly Weather Rev., Washington*, **32**, 1904 (463-465).

Teisserenc de Bort, L.—Sur la quatrième conférence de la commission internationale pour l'aérostation scientifique à Saint-Pétersbourg. *Ann. Soc. Mét. France, Paris*, **52**, 1904 (262-265).

The closing of the Ben Nevis Observatories. *Symons' Met. Mag., London*, **39**, 1904 (206-210).

Woeikof, A.—Das sommerliche asiatische Luftdruckminimum. *Meteor. Zeits., Vienna*, **21**, 1904 (502-510).

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

VOL. XXXI.] JULY 1905 [No. 135

THE GROWTH OF INSTRUMENTAL METEOROLOGY.

BY RICHARD BENTLEY, F.S.A., PRESIDENT.

An Address delivered to the Royal Meteorological Society, March 15, 1905.

(Plates 3-7.)

LADIES AND GENTLEMEN—Before proceeding to the examination of the varied collection of exhibits which awaits us to-night in the Library of this Institution—and it is of especial interest as being the first exhibition of the Royal Meteorological Society since 1897—I have been asked, in accordance with custom, to make a few preliminary remarks, and it will be more appropriate if these deal to-night with the growth of instrumental meteorology, though on glancing backward I find the ground on every side has been undermined by one's predecessors in the Chair. Still, if only acting the part of Remembrancer, there is much that it is useful to recall, and some instruments of more recent origin to refer to, though for the sake of completeness I do not wish to recite a mere catalogue to you.

Though Meteorology—so inseparably bound up with our daily life—is one of the oldest of studies, yet it is noteworthy that it is one of the youngest of the sciences.

1. As a study, we have accumulated a vast mass of historic weather materials of vague and uncertain proportions.

2. As an exact science, the power of obtaining and placing on record, by means of accurate measurement, comparative observations in physics dates back hardly farther than the opening of the seventeenth century, and only with the advent of the electric telegraph did instrumental meteorology find an effective voice, or could be turned to practical account for weather warnings.

3. As an applied science, we have now by the aid of the printing press collected from all countries a huge mass of statistics for analysis and application, and unless our efforts to digest this keep pace with the yearly output of figures, we are in danger of being overwhelmed by the very

magnitude of them. It makes one feel humble to see with how light a heart the youngest member of the staff in Victoria Street will confront the postman when laden with a heavy budget of statistics, say in Russian or Japanese characters! We have accumulated quantities of averages and extremes for all the more occupied parts of the globe, we have an international storehouse of records, but for so wealthy a country as this our means of digestion of this data is so meagre as to be a constant cause of reproach when compared with the provision made for the same purposes by the Governments of other countries. We have still, too, a Will o' the Wisp haunting us, the law of periodicity (in weather), which exercised the mind even of so competent a meteorologist as Luke Howard to arrive at, and to which we want a Newton to supply the key. We are face to face also with one great fact, even more important than the diminishing store of wheat and of coal, which is that the consumption of water in this country exceeds the average rainfall, alone a most important subject for the collection and proper analysis of our statistics, in order that adequate storage may be made of our supplies, and the present waste be prevented.[1]

To revert, however, to the first. From the time of Job to that of Aristotle, from the days of Theophrastus and Aratus to those of Virgil, we have frequent references to the keen observation of the phenomena of the atmosphere. In mediæval times the same interest is displayed. In the Library of the Royal Meteorological Society is a finely illuminated manuscript, a transcript of the notes of the Bishop of Ratisbon, better known as Albertus Magnus, on Meteorology and Natural Science, made about 1265; and at the same period in this country we have the researches of Friar Bacon in physics, also in the thirteenth century, and in the one following we have perhaps the oldest systematic record of weather—our first table of daily observations—taken by William Morley (or Merle), and reproduced in recent times by the care of the late Mr. Symons. Isolated observations of the weather abound in all the old chronicles, of storms, great cold, or devastating floods, each generally described as being the greatest in the memory of man.

As Dr. Johnson says in *The Idler* one hundred and fifty years ago, it is commonly observed that "when two Englishmen meet their first talk is of the weather. They are in haste to tell each other what each must already know, that it is hot or cold, bright or cloudy, windy or calm."

We shall all of us remember the darkness of the Crucifixion, and some of us the comet which presaged the invasion of this country by William the First; the rainbow when King John met the Barons of England assembled at Runemede; the hailstorm at the battle of Crécy. Never, says Dr. Lingard, were preparations for battle made under circumstances so truly awful. On that very day the sun had suffered a partial eclipse, birds in clouds, the precursors of a storm, flew screaming over the two armies, and the rain fell in torrents accompanied by incessant thunder and lightning. We may recall the violent storms raging during the last moments of Cromwell and of the great Napoleon; the vivid account given by Macaulay of the tempest during the burning of Elizabeth Gaunt; the graphic picture of the Great Storm narrated by De Foe; the resplendent aurora on the evening of the execution of the Jacobite Lord Derwentwater; the violence of the elements at the funerals of Mozart, Sir Walter

[1] The underground water store is steadily falling lower each year.

Scott, or Lord Palmerston; or the terrible fog during which the battle of Inkermann was fought.

Such detached particulars, however, though of considerable historic interest, are too accidentally noted to be of much scientific value. In early days too, and in the middle ages, manuscripts were few. The architect, the engineer, and the painter were able to leave their records in the very materials of their work.

Even despite its great antiquity, scanty relics connected with meteorology have come down to us from the great civilisations of the past. The knowledge of physics existed, and the expansion and contraction of air by temperature was demonstrated by Hero, the famous mathematician of Alexandria, some two thousand years ago; but the exact instruments of physical measurement were scanty.

The Greeks and Romans possessed measures of weight, length, and capacity of liquids, water-clocks, sun-dials, and wind vanes, and as far back as the time of Alexander were able to transmit messages by a form of heliograph. The scale hydrometer dates back to the fifth century.[1] The Chinese, too, contributed in very early ages the compass.

During the middle ages the arts and sciences made steady progress, with the important exception just referred to. Astronomy, geography, chemistry, navigation, literature, and painting were not stationary, and the invention of printing in the fifteenth century permitted of the wider distribution of the fruits of discovery or research.

Marine meteorology, though much invalidated through want of instruments, has its earliest archives in the log of Columbus in 1492, and of Barentz in the northern seas in 1596. Observations of the weather were systematically recorded at Nuremberg as early as 1546, and by Tycho Brahe between 1582 and 1597. Other connected observations in the following century were those of John Locke, Dr. Goad, the Grand Duke of Tuscany, de la Hire, John Gadbury, and several others.

Dr. Cunningham, a physician practising at Norwich, in the first year of Queen Elizabeth's reign brought out his *Prognostication* for 1558, showing

> "the variety of the ayre and also of the winds throughout the whole yeare, with unfortunate times to bye and sell, take medecine, sowe plants, and journey, serving for all England."

The first barometer diagram known was one sketched by Dr. Plot at Oxford in 1684. I do not know whether the term of "plotting a diagram" was thus originated, but it may be so.

The Thermometer.

The age of Faraday and Davy, of Tyndall, or Joule had not come. Speculation was, however, rife as to the problem daily presented of the four (or, after Gilbert's researches into magnetic forces, the possible five) sources of heat, the comparative measurement of which it was not possible to arrive at even among themselves: the heat given to us directly from the sun (that from the stellar system is so slender that it may be disregarded here), the heat emanating from the core of the globe, the heat artificially produced by mechanical friction or by chemical action, and the heat of

[1] One is mentioned in a letter from Synesius to Hypatia.

living bodies (especially exemplified during fever). Yet we have to wait until almost the very close of the sixteenth century before we meet with the first of the seven great weapons in our armoury.

It is to Italy, that ever fertile cradle of the arts and sciences, that we must first turn. Some immature forms of water thermoscopes had, it is believed, been many years in use for experimental demonstration when they came, just over three centuries ago, under the attention of the Professor of Mathematics at the historic University of Padua. Genius, 'tis said, is the capacity of taking infinite pains; the exact mind of Galileo was confronted, if one may be allowed the simile, by a dumb instrument, and he speedily set about devising a tongue for it, producing, it is said, in 1592 the earliest meteorological instrument with a fixed scale, and thus giving it for the first time the power of accurate expression. From this date scientific comparison became possible.

Such was the thermometer, the instrument of all others perhaps we have the most frequently in our hands. At this stage the end was open and its contents of the simplest—air and water. The scale was an empirical one, graduated to one hundred points and read in the reverse direction to that now adopted. It was, in fact, also an imperfect barometer, in consequence of the communication between the tube and the outside air. In 1739 Nelli, the biographer of Galileo, bought some of his letters describing these and other experiments, which, I grieve to say, were being used by a provision dealer for the wrapping of sausages.

In concert with Galileo, Francesco Sagredo, at Venice, with the help of the glass-workers at the Murano factory, made further improvements in the quality of the instrument, and experimentally substituted wine in lieu of water. By this time sufficient delicacy of sensation had been achieved for variations of temperature in different parts of the same apartment to be noted, or the approach of a person or lamp. The beneficent connection between meteorology and health was yet further extended beyond the influences of climate, for even at this early period the new instrument was employed by Sanctorius, a physician at Padua, for ascertaining the temperature of his fever patients. From the small pendulum machine then in use to investigate the pulsation of the blood the next step forward is the use of the thermometer.

Padua being then one of the principal intellectual centres of Europe, the scale thermometer—or thermoscope, to use its earlier name—speedily became known abroad, and many were constructed in different countries and of varying patterns. Thus we get the early types employed by the Dutchman Drebbel, the Italian Fra Paulo Sarpi, the Frenchmen Rey and Mersenne, and the Englishman Dr. Fludd, who was, by the way, a sad quack. The great Bacon (Lord Verulam), too, had one constructed.

Though not the originator, as is sometimes stated, of the thermometer, Drebbel invented, amongst many curious things, a submarine boat which travelled from Westminster to Greenwich, also machines for producing artificial rain, lightning, thunder, or extreme cold at any time. He is credited, when testing the last experiment on a summer's day before the King, to have hurriedly put to flight the whole of the spectators who had come into Westminster Hall to witness it.

The first sealed thermometer—one independent of the external atmospheric pressure—owes its origin about 1650 to the Grand Duke of


Galileus Galileus
Florentinus
Superior
licentia
16
24
12
Eques Octauius Leoni
Roman pictor fecit

GALILEO.

SIR ISAAC NEWTON.

Tuscany, Ferdinand the Second, who constantly carried about with him in his robe a small one about four inches long.

Twelve or fourteen years later Robert Hooke (whose mechanical genius was so great that he reconstructed nearly every instrument which came under his notice—clock, anemometer, barometer, telescope, or microscope alike) devised some thermometers filled with spirits of wine coloured red with cochineal, and with the zero point placed where it ought to be at the moment of freezing. Earlier than this, however, some thermometers had been made containing mercury. Wren, too, had made a registering one.

At the end of the seventeenth century experiments were made by Newton in the endeavour to arrive at a standard scale, but this was not attained successfully until the orphan—for he lost both parents on the same day when he was only fifteen years old—Daniel Gabriel Fahrenheit produced about 1714 the earliest mercurial thermometers engraved with his scale; one, unfortunately for us at the present day, with its zero thirty-two points out of place.

The earliest self-recording thermometers were probably those constructed by Cavendish, which were overflow ones.

Mr. Bolton, in his monograph on the thermometer, gives a table of thirty-five different scales; yet this is by no means exhaustive. Besides that of Fahrenheit[1] it is sufficient to-night to allude only to that of Reaumur, introduced about 1730, and that of Celsius, promulgated about twelve years later. This last, inverted at the suggestion of Linnæus, is the parent of the present Centigrade scale.

Truly no man is a prophet in his own country! The scale of the German is adopted in England and its colonies and in North America, the scale of the Frenchman is chiefly used in Germany, and that of the Scandinavian in France, Belgium, and Switzerland.

That most subtle thermometer of all—the human body—suggests as a meteorologist's dream the possibility at some yet distant day of a compound instrument being achieved to give the true perception of the atmosphere.

The Royal Statistical Society has accepted, for many years, a compound standard of value based on the combined movement of a considerable number of indices, such as gold, silver, meat, coal, corn, etc., and it has been found possible to weld together successfully these complex figures into a single index number showing the reading for each year or period.

The range of the human instrument is so large and delicate of perception that it simultaneously embraces and combines the sensation of heat (as in the thermometer), of humidity (as in the hygrometer), of air movement and consequent loss of caloric (as in the air meter), besides exhibiting indication of the ozone or electricity in the atmosphere.

How a composite reading of so many unlike elements can be similarly obtained by a mere instrument it is difficult to forecast, but for health especially the reading of sensation is all-important, and every one knows how deceptive an ordinary thermometer reading can be.

[1] As Dr. Scott points out in his *Meteorology*, the boiling-point of the Fahrenheit scale being adjusted for the latitude of London, and that of the Centigrade scale for the latitude of Paris, the common point of the two scales is actually different, but so infinitesimally as, for practical purposes, not to cause any inconvenience in the comparison of these scales.

How warm you may feel on a still dry day with perhaps fifteen degrees of frost, or how chilly with the air in movement on a moist day and temperature about 40° F. These compound readings, if ever arrived at, might be then styled degrees of comfort.

The most noticeable additions of the eighteenth century were the radiation thermometers, with bulbs—bright or blackened—*in vacuo*, of the Bishop of Llandaff, Dr. Watson; the siphon thermometer, 1781, containing alcohol and mercury, of Mr. James Six of Canterbury, with its dual record; and the plain thermometers of Dr. John Rutherford, before 1790, having the value for the first time (except those of Wren and Cavendish) of being self-registering, owing to a metal or glass float being introduced into the tube to show the highest and lowest readings of the respective maximum and minimum instruments. The maximum thermometers of Dr. Phillips and of Negretti and Zambra, in both of which the index is formed by a detached portion of the mercury itself, are well known.

The nineteenth century yields us a very large harvest of instruments. Plain metal alone, such as Crighton's zinc and iron bar thermometer; delicate spiral springs, such as Breguet's, of silver, gold, and platinum; and also another form of metal recorder of less precious material arranged with double horse-shoe springs actuating a hand on a dial.

One of the earliest clock-recording thermometers is that of Blackadder in 1826, and more than a quarter of a century ago we find a stand of twelve thermometers arranged by Negretti and Zambra, one of these thermometers being released at hourly intervals by a clock, the tube turning a somersault and so registering the temperature automatically at the prearranged time. These in turn gave place to thermographs, showing a continuous record on a clockwork drum at the side, and the pen being actuated either by a compensated strip of metal or by a sac filled with spirit. The most accurate thermograph for scientific purposes is one unfortunately not available for general use, viz. the expensive direct photographic one to be found in the observatories.

While speaking of alcohol thermometers, mention should be made of an exceedingly pretty instrument and one very sensitive to rapid change —which is in shape like a watch but only a quarter of the size, and its movement controlled by a very small spirit sac inside—the invention of Mr. Immisch, whose name was only recently removed by death from the Roll of the Society's Fellows.

Two extremely sensitive instruments may be referred to, viz. the electric differential resistance one of Professor Callendar, which is shown here to-night, and the hydrogen gas thermometer constructed for standard comparisons at Sèvres. The clock in front of me is a warning not to go too closely into the details of thermometry, even important as they are. The field embraced is indeed a large one, including for special purposes such widely different instruments as those constructed by the Rev. Richard Sheepshanks more than half a century ago, when investigating the standard of length, or those employed by Sir James Dewar to-day, when a *minus* temperature of 250° Centigrade has been achieved. Others, again, for fathoming the depths of the ocean and bringing back a message of the temperature from its bed, have been constructed to withstand a pressure of many tons. One, I believe, is exhibited to-night which will bear a pressure of eight tons.

CAVENDISH.

We have the thermometers whirled by a sling (for marine use) which Saussure originated towards the end of the eighteenth century; earth thermometers with a sluggish movement; the minute thread and finely incised scale of the clinical thermometer, employed on so many anxious occasions; the pyrometer, a veritable salamander, of the manufacturer; and the special thermometers of the brewer and sugar boiler; also that watchful guardian while we are asleep—the fire-signal thermometer, which makes its contact and starts a powerful electric alarum at a danger temperature; the thermometer which gives friendly warning of approaching icebergs to the officer of the watch in crossing the Atlantic; the salinometer, which helps the engineer in preserving his boilers at sea; and the hypsometer, invented by Wollaston in 1817, for determining heights of mountains.

We have each of us, too, in our pockets a form of thermometer in the compensating adjustment inside our watches; and as we travel home by railway to-night our safety is protected by a small curved metallic bar inside the lamp of the railway signal arm. If the flame inside the lamp goes out by the wind or want of oil or gas, and the signal post is situated round a curve, or in some position unseen by the man in the lever cabin, the little bar changes form at once and starts, by electric contact, a bell in the distant cabin. Even the temperature is roughly shown by a bottle of choice claret freshly brought from the cellar. But I am digressing from meteorology.[1]

The Sunshine Recorder.

From the first invented we pass—still dealing with heat—to the youngest of the seven primary instruments, the heliograph. The hour dial of Quirinus at Rome, 293 B.C., the sun-dial of Ahaz, and the elaborate multiple dial set up at Whitehall for King Charles the Second by Father Francis Line, first occur to us; but singularly the use of the time dial did not appear to suggest until quite lately any register of quantity also, and the heliometer invented by Savary in 1743 measured the sun itself, but not its sunshine. The sun worshippers of the East missed their opportunity, the priests at Stonehenge theirs, and even Heliopolis itself did not furnish us with any sunshine recorder. It is strange that the sun—the great source of all meteorological action—should have thus been neglected.

So, after an attempt made by a Cornish engineer[2] in 1838 to introduce a daylight recorder, it was left for Mr. John Campbell of Islay, the equally keen chronicler of Highland folklore and observer of nature, to construct in the lifetime of many now present, as recently as 1853, the first recorder in regular use, in the shape of a wooden bowl—for which many years afterwards (as will be noticed in the exhibition to-night) a gypsum one was substituted.

The sunshine recorders, broadly speaking, divide themselves into five patterns, viz.:—

(1) Those with the bowl, already mentioned.

[1] Space does not permit now of reference to the pyrheliometer, the actinometer, the radiation thermometers of Sir John Leslie, the thermometers of Count Rumford, or the metastatic one of Walferdius.

[2] Thomas Brown Jordan, at the time an instrument maker at Falmouth.

(2) Those with a photographic trace, such as the two Jordan sunshine recorders of 1838 and 1884,[1] whose action is dependent on the chemical condition of the sensitized paper, the Goddard, the Macleod, and the Dawson instruments. Some of these make their record by the motion of the earth, and some by the revolution of the paper by clockwork.

(3) Those with crystal globes, such as the Whipple-Casella, and the Campbell-Stokes recorder, introduced in 1879 with the assistance of the late Sir George Gabriel Stokes, and in which some modifications have been made by Mr. Curtis in 1901.

(4) The electric recorder of Dr. Callendar, in which the sunshine is gauged by the resistance of two platinum coils ; and

(5) The balanced thermometer introduced by Mr. Dines in 1900, which, by the expansion of its mercury in the sun's rays, tilts over on a pivot and closes an electric circuit while the sun is shining ; also one by Professor Marvin.

Sir William Crookes's radiometer has not yet been harnessed to any definite scale or turned to account for the registration of sunshine.

The most wonderful records taken have been those of the Campbell-Stokes instrument with the latest modifications, used in the recent expedition to the Antarctic regions. The trace on the blue cards will be observed to cover the entire twenty-four hours. At the particular season of the year these were taken wireless telegraphy would be much embarrassed, for it is a curious feature that while unaffected by storm, rain, or fog, the passage of signals is retarded during brilliant sunshine.

From sunshine to shadow, to cloudland, is an easy transition, though happily, as Ovid remarks, the sunny days are much the more frequent of the two.

Besides the various representations of the sky by the brush of many artists, and Turner's effort to capture on canvas the too evanescent tints of the rainbow, a singular artificial reproduction took place in London in 1782. The painter Loutherbourg, by means of lights and coloured gauzes, and similar aids, succeeded in marvellously imitating atmospheric effects at different hours of the day, and thereby won the admiration of no less keen a critic than his fellow Royal Academician, Gainsborough. This artistic display, called by him an *Eidophusicon*, attracted an enormous number of spectators, and though Loutherbourg was prosecuted for accompanying his exhibition with music without holding a license for the purpose, one was at once granted by the Justices without the exaction of any penalty. Passing to literature, we come to Shelley's beautiful poem on the "Cloud," Ruskin's description of clouds,[2] and Shakespeare's fine description of a skyscape in "Antony and Cleopatra" ; and I am indebted to Mr. Inwards for calling attention to Addison's lines on the weather, which appeared in Latin verse.[3]

The first scientific classification of clouds by form was almost simultaneously attempted in France in 1801 by the soldier, banker, and naturalist Lamarck, and in England in 1803 by the Quaker Luke Howard, who was chemist, botanist, and meteorologist ; and continued subsequently by the Hon. Ralph Abercromby, the Rev. W. Clement Ley,

[1] Another pattern of the 1884 recorder was issued at a later date, with two chambers.

[2] Besides his criticism on clouds in art in "Modern Painters."

[3] See Tickell's *Addison*, vol. vi. p. 427, "The Barometer."

and Professor Piazzi Smyth, and quite recently illustrated with the camera by your late President, Captain Wilson-Barker. The *International Cloud Atlas*, and also the very remarkable sunset pictures sketched in colour by Mr. Ascroft after the eruption of Krakatoa, will too be present to our memory.

The actual altitude and velocity of the clouds can be absolutely calculated only by trigonometry, by simultaneous observation at two stations a given distance apart and connected by electric wire; and we have in use for the purpose the cloud camera of Vettin, and one by Mr. Whipple employed at Kew. Other apparatus has been devised by Mr. Clayton and Professor Marvin for the same purpose.

Several very serviceable instruments have been devised, requiring less costly apparatus and giving approximately the direction and the movement of the clouds, such as the nephoscopes of Aimé (1845), of Fornioni, and of Finemann, which are of the nature of cloud compasses. Another ingenious instrument for ascertaining the movement of the clouds is that of M. Besson, exhibited here to-night.

To measure the blueness of the actual sky, the cyanometer was devised by Arago, whilst the photometer, for the measure of ordinary or artificial light, was introduced by Ritchie in 1825.

The Hygrometer.

One of the more ancient instruments in use was the hygrometer, and one of the earliest forms of it was the weighted woolpack of Cardinal de Cusa in the fifteenth century, which calls to mind the fleece of Gideon. Many even simpler substitutes for the same purpose have been used, from the bunch of seaweed to the bearded oat, the toy "Man and Woman," so-called weather indicator, to the tinted landscape pictures, which, chameleon-like, altered their hues with moisture, or the hair hygrometer of de Saussure.

Though the scheme of a hydroscope has been attributed to Leonardo da Vinci, the first actual scientific instrument for hygrometry we owe to the philosopher Grand Duke already referred to, Ferdinand the Second of Tuscany, somewhere about 1660, who employed snow or ice, measuring the amount of the condensation on the outside of the vessel.

Wet bulb thermometers were in use by Baume as early as 1758, and by de Saussure in 1786.

John Coventry, an instrument maker, and friend of Benjamin Franklin, constructed about 1770 a new form of hygrometer more accurate than its predecessors, and another hygrometer was constructed by John Dalton, whose discoveries in regard to the evaporation and expansion of the gases of the atmosphere have done much to advance the science of meteorology. Dalton's hygrometer dates back to about 1802.

De Luc, when he came from Geneva to Windsor and was in attendance at the court of George III., devoted all his available time to scientific research, and, amongst other experiments, constructed about 1773 a very curious form of hygrometer, consisting of an ivory bulb filled with mercury and provided with a glass stem like an ordinary thermometer. The ivory, he claimed, expanded and contracted according to the amount of water vapour present in the atmosphere, and the mercury as it rose or fell in the tube was an index of such alteration.

About 1805 another hygrometer, a self-registering one, was invented by a Scotch divine, Dr. Robert Gordon, when at Aberdeen; and yet another form was constructed by Thomas Jones, a London optician, in 1824.

The best known hygrometer about this period, however, was that of John Frederic Daniell, introduced in 1819, and manipulated by the assistance of ether; and this was modified and improved by Regnault.

One more readily adapted for common use, and requiring no ether, was constructed by Mr. George Dines; and a still simpler form is to be seen in the dual (dry and wet bulb) thermometers of Mason, for which also Dr. Hutton and Sir John Leslie stand as sponsors. Sir John Leslie employed, however, sulphuric acid in lieu of mercury.

A later psychrometer is that of Professor Assmann, termed an aspirator (I think lately Lieutenant Royds mentioned that another name had been found for it in the Antarctic regions—an "exasperator" from the trouble in reading it in that severe climate), as the air is artificially drawn up past the bulbs at the time of reading.

Many other hygrometers have been designed from time to time, but have fallen into disuse—some indeed as soon as born. By the industry of the late Mr. Symons a list of these, extending to many pages, will be found in the April 1881 issue of this Journal.

In connection with the topic it is hardly necessary to recall the researches of Dr. Wells in 1814 or of Professor Tyndall on the subject, or to mention the tables in daily use drawn up by Mr. Glaisher.

The Rain Gauge.

We now pass to the measurement of precipitation. Dante, who in the opening years of the fourteenth century divined the action of light on the processes of the ripening of fruit, and noticed the circumstances which influence the colouring of the foliage of plants and something of the mysterious circulation of their juices, made also a keen scrutiny of atmospheric phenomena.

His reflections on the rainbow, on the scintillations of the stars, and on the vapours of the atmosphere, are equally pregnant, while his theory of rain is alike remarkable for its truth and conciseness:—

> Ben sai come nell' aer si raccoglie
> Quell' umido vapor che in acqua riede
> Tosto che sala dove 'l freddo il coglie.
>
> *Purgatorio*, v. 109.[1]

In the politically eventful year of 1715 Edward Booth—better known perhaps as Father Barlow, and as the inventor of repeating watches—published his essay on the generation of rain four years only before his death at the ripe age of eighty; and in 1792 James Hutton, the geologist, formulated the theory of rainfall being due to the conflicts of currents of air of varying degrees of warmth, and investigated the percentage of moisture possible in the air proportionate with an increase of temperature. Yet another writer on the theory of rainfall, early in the last century,

[1] "Thou knowest how in the atmosphere collects
That vapour dank, returning into water,
Soon as it mounts where cold condenses it."

SIR CHRISTOPHER WREN.

was George Augustus Rowell, one of the Curators of the Oxford University Museum.

Probably the earliest scientific measure of rain is the gauge devised by Sir Christopher Wren about 1662, and it is characteristic of its inventor that instead of being in the ordinary form of a plain receptacle it was fitted with a tipping bucket as a record. Rain-gauges may be classified under five heads, namely: (1) the common form of funnel and bottle; (2) the tipping balance; (3) the weighing gauge; (4) the float gauge; (5) the tube. The adjunct of the clockwork drum or electric recording apparatus is a valuable modern addition, as well as is the means of warming the gauges to melt the snow applied during the last half-century.

Until Wren's gauge we have no record of any special instrument for local measurement, and are dependent only on indirect inference as to the amount of rainfall, such as, for example, the nilometer, or, to-day, the huge tanks at Aden, or from flood marks in the valleys. We not only owe the rain-gauge to Sir Christopher, but should remember once a year when we ascend to that shrine of science, how largely the Royal Observatory at Greenwich is indebted for its erection to his ability. We may thus compute by Wren's invention the age of the modern rainfall measure as close upon two hundred and fifty years.

Hooke followed in the wake of Wren, but with a simpler form of gauge, in which the precipitation was merely collected and then weighed independently by hand. The weight did not automatically register itself on the scale.

The longevity of meteorologists has often been the subject of comment, and a remarkable illustration presents itself in the ages of four of the earlier constructors of rain-gauges, Wren dying in his ninety-first year, Lukin in his ninety-second year, Howard in his ninety-second year, and Glaisher in his ninety-third year; these four lives amounting to 368 years.

I have just mentioned another case—that of Father Barlow (eighty). The fragility of health of Wren and Hooke, and the forty-eight years of the torture of rheumatism endured in the last half of his life by Galileo, still did not seem to militate against the adage. Another meteorologist, an Honorary Treasurer of this Society, Mr. Perigal, died not long ago at the advanced age of ninety-seven.

On the other hand we have two well-known instances of victims to the weather, that of Viscount St. Albans, the great Bacon, who caught a chill while making an experiment with snow at Highgate, and of the author of *The Pilgrim's Progress,* who caught his death-chill riding in a pouring rain from Reading to London.

Yet another instance of longevity presents itself in the case of Dr. William Heberden, the physician of Dr. Johnson, who died at the age of ninety-one. Dr. Heberden was the first to observe, in 1766, the discrepancy of rainfall at various heights in the same locality. Nearly a hundred years previously, however, a consecutive record of rainfall was taken, from 1677, by a member of the well-known family of Townley, of Townley Hall in Lancashire (from whom the Townley Collection passed to the British Museum).

The inventor of the lifeboat, one Lionel Lukin, a fashionable coachmaker in London, constructed, more than a century ago, a gauge with

which he took observations of the rainfall, as did similarly Luke Howard in the opening years of the nineteenth century, with a funnel placed over a bottle.

Mr. Glaisher's gauge differed slightly from the others by possessing a small U trap in the funnel, which was liable to get blocked.

In 1842 a first series of experiments was conducted to ascertain the best form of gauge for the measurement of rain, supervised by Mr. Thomas Stevenson, the lighthouse engineer; and ten years later M. Quetelet, the eminent Belgian statistician and man of science, made some further experiments.

1859 was a memorable year in regard to rainfall, for during it Mr. Symons laid the foundation of his great work, the British Rainfall Organisation, and a year or two later (in 1862-63), in conjunction with Colonel M. F. Ward at Calne, made further and very complete experiments both into the sizes and shapes of the gauges and their height above the ground, etc., thus rendering possible the adoption in this country of a standard pattern of the ordinary gauge. In 1872 Dr. Angus Smith published his researches into the chemistry of air and rain. In 1873 an International Meteorological Congress was held in Vienna with a view to assimilating the methods of observation.

Few scientific instruments, except the chronometer, have occupied the ingenuity of inventors so constantly as the rain-gauge. Picture the contrast between Colonel Ward's pigmy one-inch receiver and the giant one of five hundred inches across erected half a century ago at Rothamsted; or compare a storm-gauge with its whitened cork index balls rising in glass tubes with one of the rotating gauges or those with vertically placed mouths used for a time in Yorkshire, at Rotherham. Another curiously designed gauge exposed for an instant sheets of prepared paper like blotting-paper, on which the raindrops left a record of their size. What is still more important, we are now able to ascertain automatically by the aid of clockwork the speed at which rain falls—a matter of extreme value to the civil engineer or to the builder. One of the earliest of the gauges of the Victorian era was Mr. Follet Osler's, which was combined with an anemometer, both the wind and rain trace showing on the same sheet of paper. The rain-gauge in this case was complicated by the addition of spiral springs below the receiver.

The gauges with a simple construction actuated either by a tipping bucket or a balance beam are numerous. Some are fitted with electric registration, and some with a wheel index (such as Crosley's), and others with clock-drum and pen, such as Negretti and Zambra's or Richards'; and another ingeniously contrived instrument is that set up at Kew by Mr. R. Beckley.

One of the newest gauges for your inspection to-night is a siphon one designed by Mr. Halliwell of Southport.

One of the most important forms of rain-gauge it is impossible to show here to-night, as it is a kind that can only be inspected *in situ*, the percolation gauge, for ascertaining how our underground water-supply is fed. A few of the better known gauges of this class may, however, be named, viz. the Nash Mills gauge, established by Sir John Evans in 1854; that at Lea Bridge in 1860; the gauges of Sir John Bennet Lawes and Dr. Gilbert at Rothamsted in 1871; one at Apsley Mill; Mr. Baldwin

TORRICELLI.

Latham's at Croydon; Mr. Mawley's at Berkhamsted, etc., by which readings are taken at various depths and underneath different sorts of soil.

We now pass to another form of moisture gauge, the evaporators, atmidometers, or atmometers, some of the earlier observations with which were conducted by Dr. John Dalton, Mr. John Dickinson (1836), Dr. Babington, Luke Howard, Major Phillips, Mr. Greaves (1859), Mr. George Dines, Sir John Evans, Mr. Symons, Rev. C. H. Griffith at Strathfield Turgiss, Mr. Rogers Field, and Mr. Baldwin Latham. A most interesting comparison by natural means with some of these observations was undertaken between 1861 and 1875 by Mr. Miller of Wisbech in registering the amount of moisture evaporated from plants.

The simplest form of evaporation gauge is a dish or tank from which any added rainfall is deducted, but which is liable to loss from the occasional drinking of birds or animals if insufficiently protected. A very pretty arrangement is that of Messrs. Richard of Paris, consisting of the adoption of a scale beam balance between a fixed weight and the liquid from which evaporation takes place. Another form is de la Rue's, where a target of moist paper is kept fed from a glass reservoir, the decrease of whose contents gives the measure of the evaporation. A similar one made by Richard is shown here to-night. A very simple form is Piche's tube, on which is an engraved scale. When filled with water it is inverted, its open end standing upon a sheet of porous paper, which slowly abstracts the liquid from the tube above.

More than a quarter of a century has elapsed since Professor Piazzi Smyth introduced the examination of the spectrum for the rain-band. The spectroscope has, however, fallen into disuse for meteorological purposes.

THE BAROMETER.

The second in importance of our seven greater instruments to refer to is the barometer, which in its simpler form has practically remained unaltered from its birth.

As all will remember, its origin was in Italy and its discovery due to a pupil and amanuensis of Galileo, Evangelista Torricelli, in 1643, and it was christened by the name now so familiar to us by Boyle. While referring to the selection of words it may perhaps be interesting to note that we are indebted to Henry Piddington for that much used word "cyclone," to Thomas Stevenson, the engineer of the Northern Lighthouses, for the well-known phrase "the barometric gradient," and to Francis Galton for the term "anti-cyclone." Many and various have been the devices for measuring the weight of the air, from empty barrels buried in the ground to measuring the oscillations of water in the mines or in wells, and another extremely simple one was in the form of a flask inverted in a water vessel.

Changes of weather have also been foretold by means of leeches and green frogs in bottles, and by flocculent camphor and nitre in tubes of glass. William Cowper the poet writes to Lady Hesketh, November 10, 1797:—"Yesterday it thundered, last night it lightened, and at three this morning I saw the sky as red as a city in flames could have made it. I have a leech in a bottle that foretells all these prodigies and convulsions of nature, etc." In the great Exhibition of 1851 was Dr. George

Merryweather's "Tempest Prognosticator or atmospheric electro-magnetic telegraphic conducted by animal instinct," by which leeches were induced to ring a bell as a signal of an approaching storm.

In the eighteenth century there used to be a water barometer 34 feet long at Trinity College, Cambridge, ascribed to Roger Cotes, and fixed near the rooms occupied by Sir Isaac Newton. The similar one at the Royal Society's apartments, constructed in 1831 by Daniell, is well known.

The wheel or clock-dial barometer was devised by Robert Hooke about 1666, and another quaint form of pressure indicator was constructed by de Guericke at Magdeburg in 1661, with the legend inscribed thereon of "*Semper vivum.*" Gay-Lussac, who came to the front under the first Napoleon, was the inventor of the siphon barometer.

One well-known pattern of mercurial instrument is the Fortin barometer, which, however, requires a very careful adjustment while being read; and a yet more widely known instrument is the Kew pattern, one introduced by Mr. Adie in 1853, with a somewhat more contracted bore.

Several attempts have been made to obtain an extended scale of reading. In 1772 Sir Samuel Morland, the engineer, devised a bent tube one, called by him "the diagonal barometer." Another was constructed by Mr. Howson, in which, by an especially ingenious device, the cistern is free of any attachment and is suspended apparently against gravity by the upward pressure of the air, and another designed by Mr. M'Neild, which reverses this process, the tube in this case being free and floating on the cistern, as in the barograph of King at the Bidston Observatory mentioned below.

A recent development claims your attention to-night in the micro-barographs shown by Dr. Shaw and Mr. Skinner, designed to show the more rapid oscillations of pressure only, but this on a magnified scale. The natural slower movement of the instrument is eliminated for the purpose by a very fine leak inserted in the air chamber.

In the barographs used at Greenwich and Kew, designed by Mr. Brooke and Sir Francis Ronalds respectively, the register is taken photographically, though the mode is in each case slightly different. Another fine recording instrument was that designed in 1853 by Mr. Alfred King for the Bidston Observatory, the reading being magnified by the tube being a floating one. There are a large number of barographs now in popular use with either pencil or pen registering on a clock drum. Some are fitted to mercurial instruments, but a large proportion to aneroids. One designed by Admiral Sir Alexander Milne in 1857 is parent to several styles of mercurial barographs.

In 1843 a new form of barometer (known as the aneroid) was invented by M. Vidi, consisting of a vacuum chamber to which an index hand was connected to show the expansion and contraction of the chamber under the varying pressure of the external air.

Somewhat similar in principle, though differently arranged, is Bourdon's holosteric instrument, brought out in 1851.

Another application of similar character will be seen in the instrument designed by the former Director of the Observatory at Manila, Father José Algué, for the use of mariners and others inhabiting islands in the eastern seas. It is entitled the "baro-cyclometer," and is a compound of

aneroid and compass, with pointers to indicate the approximate direction of the vortex of a cyclone.

A large-scale instrument came out in 1880, viz. the Jordan glycerine barometer—the glycerine coloured with cochineal—and was succeeded in compactness by a compound barometer, also known by Mr. Jordan's name, in which mercury was employed and the glycerine used only as the index for the scale.

A hybrid between barometer and thermometer, but used as a sensitive form of barometer, has now gone almost out of use—the sympiesometer, invented by Adie in 1819.

Another form of barometer—which might almost be described as a barometer within a barometer—is the carefully guarded statoscope in use for very delicate observations. Robert Boyle's manometer was one of these.

The Anemometer.

According to Seneca,[1] the ancients before his time did not know the difference between the winds, and could not even distinguish Boreas from Zephyr. Most probably, however, they had not agreed upon a common nomenclature.

One of the oldest—and before the days of steam navigation, one of the most necessary—instruments of observation was the wind-vane, and both the Romans and the Greeks had some very beautiful examples of these. Some were in very graceful form, others were connected with a dial indicating the direction inside the building. Indeed, occasionally entire buildings were erected to indicate the direction of the winds (and perhaps to propitiate the deities presiding over them), of which the most memorable are the Temple of the Winds at Athens, the great column at Constantinople surmounted by a female figure that turned with every wind, and a tower at Emesa in Syria, on which was a copper statue of a horseman moved by the wind.

In classic days more often the triton—in mediæval days the emblem on the church most used was the cock, in remembrance of St. Peter and the duty of Christians. The Norman fleet which crossed over to England in 1013 had ornamental vanes, representing large birds, at the tops of the masts, which swung round with the wind. In France the right of using wind-vanes on buildings was reserved, like that of standards, in the twelfth century for nobles only.

The registering vane owes its origin in the seventeenth century to Wren:—"Because the difficulty of a constant observation of the air by night and by day seemed invincible, he therefore devised a clock to be annexed to the weather-cock, so that the observer by the traces of a pencil on the paper might certainly conclude what had blown in his absence." [2]

The direction trace is now fitted as an ordinary adjunct to nearly all anemometers. A few years ago another direction recorder was devised, by which the rod of a wind-vane caused a very small water receptacle attached around it to rotate indoors. A minute jet of water kept this small reservoir charged, and an equally minute one slowly continued to

[1] In the *Medea*.

[2] Dr. Spratt, Bishop of Rochester.

drop from it below. The aperture for the escaping water revolved with the vane, and discharged it into one of eight tubes marked to correspond with the compass points. At the end of the day the proportion of water in each tube affected indicated instantly by the scale on the tube the proportion of the direction of the wind, without any calculation or measurement of trace being necessary. In very cold climates this automatic apportionment was to be carried on by sand instead of water.

No one with maritime experience had undertaken the construction of an anemometer, so we turn to the architect and are not disappointed. Wren, it has already been mentioned, invented a direction recorder.

Robert Hooke—also during part of his life an architect—endeavoured to ascertain the speed of the passage of air by musical means, the varying speeds being indicated by special notes transmitted by a modified series of pipes. In after years Leslie endeavoured to gauge the speeds of impinging currents of air by the cooling of a thermometer, and Brewer similarly attempted to deduce their velocities by the speed of evaporation, but was baffled by the dry or moist alternations of the atmosphere.

Hooke produced an anemometer about 1666, and Martin one somewhat like Hooke's a little later; and yet another was perfected by Wolff in Germany in 1709. It is somewhat singular, perhaps, in an age of windmills, that the evolution of some form of anemometer should have been so tardy.

About 1774 Dr. Lind, a physician to the Court at Windsor, came out with a portable anemometer, of a truer type than the revolving cup one afterwards so much in vogue, but one which failed from its small dimension and from being constructed only for occasional readings. Science was not then treated with the same respect as it now is. "With his love of Eastern wonders and his taste for tricks, conundrums, and queer things," says Madame d'Arblay of Lind, "people were afraid of his trying experiments with their constitutions, and thought him a better conjuror than a physician."

The next anemometer produced was one by Richard Lovell Edgeworth —the husband of many wives, and father of the celebrated novelist— in 1783, and in consequence of which Dr. Robinson later made his experiments at Armagh in 1846. Curiously enough, the Thibetans in the eighteenth century possessed some rude wooden ones resembling the Robinson pattern.

A Royal Engineer, Samuel Howlett, also invented an anemometer about 1824. The customary method of measurement was, however, still only the very crude one of estimation by the individual, and referred to Admiral Beaufort's scale introduced in 1805. Dr. Whewell of Cambridge, the great investigator of the tides, gave us in 1840 too an anemometer, but one not often met with at the present day, though its principle has been revived by M. Richard. Mr. Follet Osler produced a very valuable but costly instrument in 1836 (?), improved in form in 1862, in which a pressure plate impinging on springs is made use of, and the results recorded continuously by clockwork. Mr. Richard Beckley brought into use at Kew about 1857 another form of anemograph, also somewhat costly, employing Robinson cups and also a double fan wheel for the direction; and Dr. Robinson's cup machine has also been modernised by recording at a distance electrically.

Mr. Cator in 1864 indicated the force of the wind by means of levers, but in most other respects his instrument resembles Mr. Osler's.

One of the most elaborate instruments was Father Secchi's electric meteorograph, exhibited in Paris in 1867.

The most recent form for recording wind force is the pressure-tube of Mr. W. H. Dines, brought out in its first form in 1891.

Very delicately constructed instruments are the little hand air meters for use in buildings or mines; but they require close watching, as they run backwards as well as forwards in counter currents of air.

The fearful disaster of the Tay Bridge was partially repeated, happily with less fatal result, but two years ago near Ulverston, on the Leven viaduct, when a train was blown over in a February gale. I only refer to the matter to show how the meteorologist steps in. The Furness Railway have since erected on the viaduct in question, a very exposed one, a wind pressure-gauge and recorder, connected by electricity with the signal cabins on each side. If the wind exceeds a certain velocity, warning is instantly given automatically by the ringing of a bell in the signal cabin, and the traffic is stopped until the wind moderates. A similar apparatus is in use, I believe, on the North-Eastern Railway, to guard trains running over the Whitby viaducts.

On the Tower Bridge in London will be found some of Mr. Dines's pressure-gauges, and others of different pattern have been erected on the Tay and Forth Bridges. Lord Dufferin's description of the storm in northern seas (in his *Letters from High Latitudes*), or Pierre Loti's (in his *Pêcheur d'Islande*), or Lord Roberts's description of a Calcutta cyclone (in his *Forty-One Years in India*), will be in the memory of most present.

The Meteorological Kite.

Even if not entitled to include balloons as meteorological instruments, one cannot wholly pass them by. The first "manned" balloon was that of Montgolfier in 1783; the first military one appeared in that same century at the battle of Fleurus.[1] In 1852 Mr. John Welsh, of Kew Observatory, made four ascents for meteorological purposes in the great Nassau balloon, immortalized by Thomas Ingoldsby; while the historic ascent of Mr. Glaisher and Mr. Coxwell in September 1862 has only once been surpassed. Among the interesting features of the exhibition to-night are some of the instruments used by Mr. Glaisher in his ascents. It is but recently that we have had to deplore the death of another one-time Fellow of the Society who was also an explorer of the upper air—the Rev. J. M. Bacon of Newbury.

Bishop Wilkins, as far back as 1651, said, "It will yet be as usual to hear a man call for his wings when going on a journey as it now is to hear him call for his boots."

Amongst the instruments for the exploration of the upper air, apart from balloons, we have kites. The name of Franklin naturally first occurs to the lips, but more in connection with electrical investigation. The earliest purely meteorological use of the kite appears to have been that of Alexander Wilson, in the neighbourhood of Glasgow, about 1749,

[1] Used by General (afterwards Marshal) Jourdan on June 26, 1794.

followed nearly a century later by the experiments in 1847 of Sir Francis Ronalds and Mr. Birt at Kew to keep a kite at a constant height for the purpose of meteorological readings.

In more recent times great use has been made of kites of divers shapes by Mr. Archibald in 1882, Mr. A. L. Rotch at Blue Hill, near Boston, in America; by Major Baden-Powell, by Mr. Cody, and by Mr. Dines in this country; and by M. Teisserenc de Bort and M. Hergesell on the continent.

A very complete kite meteorograph has been designed in the United States by Professor Marvin, and a still newer one has been devised by Mr. Dines, combining great strength, simplicity, and lightness.

Other Instruments.

So, too, it is important to be able to measure the density of fogs by instrument, even if we are unable to dispel them, as Sir Oliver Lodge suggests, by electricity. Fog has been liquefied by Sir James Dewar, who a month or two ago imprisoned some fog-laden air in London, and carried it to Edinburgh for examination. A curious index to their intensity during the past winter was expressed in an £ *s. d.* scale in the half-yearly railway reports, showing, in one way alone, how great their cost is to the community. Their effect on health is also shown statistically. In a single week last December the death-rate rose at Manchester from 21½ to 26½ per thousand.

> In London (said M. Bénédite, the Conservator of the Luxembourg Gallery, recently) you get marvellous effects of atmosphere. Then there is the animation, the seething (*grouillement*) of the streets. The fog gives you richness of tone and strange lights. We had one wonderful day during our stay. We stood looking at the river from the Embankment. There was a roseate hue on the edge of the fog, out of which rose glorified the towers of Parliament, and in the foreground were the clear-cut outlines of the passing boats. There is that in the atmosphere of London that seems to neutralise the most glaring colours. You must know London and its fogs properly to understand Turner, just as to understand Corot you must know the fine grey atmosphere of Paris.

A sunset, too, as we all know, witnessed through murky clouds like the smoke of a battlefield, over Hyde Park, is a fine sight. An instrument has been contrived by Mr. John Aitken, however, which would have pleased the historian Gibbon, who once wrote to Holroyd:—

> Never pretend to allure me by painting in odious colours the dust of London. I love the dust.

Mr. Aitken's dust-counter, brought out in Edinburgh in 1892, is one of considerable utility, as it enables a correct record to be taken of the amount of dust particles in the air, and one of these counters was, for a time, in use at the Observatory on Ben Nevis.

Another form of receptacle is in use for the collection of living germs from the air, and yet a third for taking samples of air at different heights.

Ozone in the atmosphere was first detected by Schonbein in the year 1840, and an apparatus has been used to measure it; but the results are too uncertain for any extensive use to be made of it.

Meteorology in its modern aspect was virtually dumb until the advent

of the electric telegraph. While Sir James Dewar has unlocked the secrets of fresh gases and Sir William Ramsay of new elements, Signor Marconi has covered the Atlantic with a forest of telegraph poles. By the enterprise of one of our daily newspapers tidings of the weather reach us daily from mast-heads far out on the ocean.

As early as 1831 the Admiralty endeavoured to collate weather reports received from vessels, but funds were wanting for maintaining an adequate service of information, as well as electric cables.

The first forecasts were made possible by the reports issued daily in 1851 by the Electric Telegraph Company, of which a copy of the first map is shown this evening. The establishment of the Meteorological Office in 1855 gave further development to what is now become a system of the highest public utility.

In the late seventies, when the weather telegrams of the *New York Herald* were often being discussed in this country, and on one occasion in the presence of an old Yorkshire farmer's wife, she said, "I do wish God Almighty would take the weather into His own hands and not leave it to those Americans!"

Amongst the instruments allied to meteorology we can include the air-pump, invented by de Guericke as far back as 1654, and a necessary adjunct for the testing of aneroids; the seismograph, for recording earth tremors, which would be somewhat outside our province, except when its records are taken in conjunction with aerial disturbances, and with the same proviso several instruments employed in registering magnetic observations.

In the case of electrical disturbances we have the electrometer, and, more especially for the study of thunderstorms, the brontometer devised by the late Mr. Symons.

For protective purposes, and therefore hardly within our scope, though any instances of damage to them find place in the pages of our Journal, we have the lightning conductor, some of the earliest experiments with which are the familiar ones of Franklin, Daniell, and many others.

The introduction of photography by Wedgewood, Brooke, and Ronalds, and the fixing of the negative by means of hyposulphite of soda by Sir John Herschel, have given us a most valuable handmaid in the camera for pictures of clouds, lightning, floods, snow, and similar objects. The use of sensitized paper in the Jordan sunshine recorder has already been alluded to, and for other automatic records the printing paper is of great daily service, as well as the application of clockwork, which now renders possible an unbroken series of observations.

Sundry minor aids, such as the cathetometer, the vernier, and the magnifying lens on the tube of the thermometer need not now be dwelt upon.

Audibility remains, however, to be taken further in hand, and should be helpful, though in a lesser degree than visibility, in judging of weather conditions. The acute sense of hearing of the blind might enable some investigation to be made in regard to weather and audibility.

The various instruments used out of doors have to be suitably housed to perform their duties accurately, and various patterns of shelters have been designed, those most commonly met with being the Glaisher screen, in use at Greenwich, but which has the disadvantage of having to be

turned daily, the Stevenson screen with wooden louvres, in general use in this country, the screen of M. Renou employed in France, that of Professor Wild in Russia, and that of General Hazen in the United States.

Of the seven greater instruments, if we assign the origin of the Thermometer, Hygrometer, and Barometer to Italy, we endeavour to claim for England the Sunshine Recorder, the Rain-gauge, the Anemometer, and the Meteorological Kite.

The instruments mainly employed in the service of meteorology are given below. The most important ones are shown in the first column, and where possible the conjectural date of their discovery is appended.

To indicate warmth or the reverse.

I. THE THERMOMETER (Italy, 1592)	Thermometers of various kinds for furnaces, extreme cold, pyrheliometers, deep-sea thermometers, and sub-soil ones.
	The Hypsometer (for altitudes).
II. THE SUNSHINE RECORDER (England, 1853)	The Sun-dial.
	The Nephoscope.
	The Cyanometer.
	The Photometer.

To indicate wet or the reverse.

III. THE HYGROMETER (Italy, 1660)	or Psychrometer.
IV. THE RAIN-GAUGE (England, 1662)	The Percolation Gauge.
	The Evaporator.
	The Spectroscope (for rain-band).

To indicate the weight of the atmosphere.

V. THE BAROMETER (Italy, 1643)	Aneroid and various patterns of Barometers.
	Sympiesometer.
	Micro-barograph.

To indicate the pressure and direction of the wind.

VI. THE ANEMOMETER (England, 1666)	The Wind-vane.
	The Air Meter.
VII. THE METEOROLOGICAL KITE[1] (England, 1749)	The Balloon (France, 1783).

The Electrometer.
The Brontometer.
The Ozone Cage (1840).
The Dust-counter.
The Seismometer.

The Screens.
Electric Recorders.
Clockwork recording apparatus.
Photographic recording apparatus.
Cloud Camera.

Phenological Records.

[1] The meteorograph is a compound recorder devised for use with kites.

EXHIBITION OF METEOROLOGICAL INSTRUMENTS.

March 14-17, 1905.

(Plates 8 and 9.)

The Royal Meteorological Society from 1880 to 1892 held an annual Exhibition of Meteorological Instruments, each of which was devoted to some particular class of instrument. Exhibitions were also held in 1894, 1897 and 1900.

The following list shows the special features of each Exhibition:—

1880	General.
1881	Hygrometers.
1882	Anemometers.
1883	Travellers' Instruments.
1884	Thermometers.
1885	Sunshine Recorders.
1886	Barometers.
1887	Marine.
1888	Atmospheric Electricity.
1889	Actinometers and Solar Radiation Instruments.
1890	Application of Photography to Meteorology.
1891	Rain Gauges.
1892	Climatology.
1894	Clouds.
1897	Instruments in use in 1837 and in 1897.
1900	General (Jubilee Conversazione).

FIG. 1.

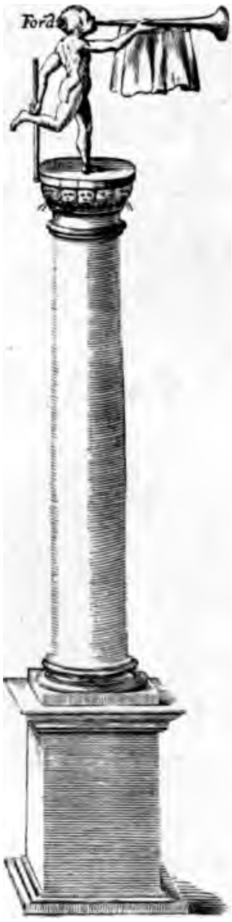


FIG. 2.—ANEMOMETER DEVISED BY P. VALENTIUS PINUS ABOUT 1650.

When the Council decided that an Exhibition should be held in 1905 it was considered that it might appropriately be devoted chiefly to "Recording Instruments," and that it should also include new Meteorological Apparatus invented or first constructed since the last Exhibition,

as well as Photographs, Drawings and other objects possessing Meteorological interest.

By the kind permission of the President and Council of the Institution of Civil Engineers, the Exhibition was held in their spacious Library, Great George Street, Westminster. The instruments were grouped in classes on tables, and a typical Climatological Station in a railed-off enclosure occupied the centre of the room.

The Exhibition was open on Tuesday, March 14, from 2 p.m. to 9.30 p.m.; Wednesday 15, from 10 a.m. to 9.30 p.m.; and Thursday 16 and Friday 17, from 10 a.m. to 5 p.m.

Mr. W. Marriott gave a brief Address each afternoon at 3.30 p.m., descriptive of the instruments included in the Exhibition.

On the front of the cover of the Catalogue was printed a representation of the Tower of the Winds, and on the back the Anemometer designed by P. Valentius Pinus about 1650. These are reproduced in Figs. 1 and 2 (p. 193).

Views of the Exhibition are given in Figs. 3, 4, 5, and 6 on Plates 8 and 9.

The List of the Exhibits is reprinted herewith. Nos. 72, 116, and 144 (which are enclosed in square brackets) were, however, not shown.

CATALOGUE OF EXHIBITS.

Section I.

INSTRUMENTS.

Rain Gauges.

1 **Fleming's Float Rain Gauge.**
A copper rain gauge with float and thin metal rod graduated to show the rainfall directly. The diameter of the gauge is 3 inches, and the rod is fixed permanently to the float. This pattern of gauge is still occasionally used in Scotland.
Exhibited by Dr. H. R. Mill, F.R.Met.Soc.

2 **Stevenson's Side-tube Gauge.**
The funnel has an expansion below the rim designed to prevent outsplashing. It is read by the height of the water in a side-tube, the scale for which is engraved on the copper of the gauge. This pattern is obsolete. *Exhibited by* Dr. H. R. Mill, F.R.Met.Soc.

3 **Experimental Rain Gauges.**
These are some of the instruments employed in 1868 at Strathfield Turgiss to investigate the effect of different forms and sizes. Those shown are a 2-inch and a 12-inch circular, and a 5-inch and a 10-inch square gauge. *Exhibited by* Dr. H. R. Mill, F.R.Met.Soc.

EXHIBITION OF METEOROLOGICAL INSTRUMENTS.

March 14–17, 1905.

Fig. 3.

Fig. 4.

EXHIBITION OF METEOROLOGICAL INSTRUMENTS.

March 14–17, 1905.

FIG. 5.

FIG. 6.

4 **Dial Storm Gauge.**

Used by the late Mr. G. J. Symons for measuring heavy falls of rain in short periods. The rising of a float actuates clock hands, which show the fall in inches and hundredths on a dial.

Exhibited by Dr. H. R. MILL, F.R.Met.Soc.

5 **Beckley's Self-Recording Rain Gauge,**

in use at Fort William Observatory from 1890 to 1904.

Exhibited by the METEOROLOGICAL COUNCIL.

6 **Richard's Self-Recording Rain Gauge.**

This consists of a funnel for collecting the rain and a pipe leading it into the reservoir in which there is a float. A style, carrying a writing pen, follows the motion of the float, rising 4 ins. for a rainfall of 0·4 in. When the pen reaches the top of the revolving drum the reservoir empties itself, the float falls to the bottom, and the pen returns to zero. The emptying of the reservoir is automatically obtained by a siphon, the starting of which is secured by an electro-magnet, which, on the circuit of a battery being completed, pulls the float down and causes a sudden rise of the water-level, thereby filling up the siphon.

Exhibited by Messrs. J. LEVI & Co.

7 **Richard's Self-Recording Rain Gauge, balance pattern.**

This consists of a funnel and pipe leading the rain into a tipping bucket divided into two compartments and placed on a balance. One of these compartments being under the funnel, the rain falls into it and causes the balance to descend; a writing pen records this motion on the revolving drum. When the pen has reached the top (0·4 in. of rain) the tipping bucket reservoir oscillates, and the water filling the first compartment is emptied into a controlling reservoir. This motion causes the second or empty compartment of the bucket to place itself under the funnel. The filling and emptying of each compartment are alternately and automatically produced, and to each of these double operations corresponds a rise and a fall of the writing pen.

Exhibited by Messrs. J. LEVI & Co.

8 **Rain Gauge, with Baxendell Hot-Water Chamber underneath the Funnel,**

for melting collected snow without loss from evaporation and without any admixture of the hot water with the melted snow.

Exhibited by J. BAXENDELL, F.R.Met.Soc.

9 **Halliwell's Improved Float Pattern Pluviograph.**

Self-Recording Rain Gauge, 1905 Pattern.

Exhibited by F. L. HALLIWELL.

10 **Negretti & Zambra's Self-Recording Rain Gauge.**

A tilting bucket divided into two equal parts, tipping over when ·01 inch of rain has fallen, advances an escapement wheel one tooth, and by means of a perfect helix attached to this wheel the long lever carryin the pen is gradually raised until an inch of rain has fallen. When this spot is reached, the lever falls to the other end of the helix, the recording pen runs back to zero, and begins to record a second inch—so that there is no limit to the quantity of rain that can be recorded.

In addition to the ink record on the chart, the quantity of rain fallen at any time can be read from the divisions on the escapement wheel to ·01 inch. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

11 **Negretti & Zambra's Electrical Self-Recording Rain Gauge.**

In this instrument the gauge and tilting mechanism are placed out of doors and the recording mechanism can be placed indoors. The transmitter is similar to No. 10, but the bucket in tipping makes contact and closes an electric circuit. The recorder is constructed on the principle of an escapement motion attached to a perfect helix, which raises the lever arm and pen by steps of ·01 inch until 1 inch of rain has fallen, when the pen descends steadily and is ready to commence another inch. The escapement is set in motion by the attraction of an armature to an electro-magnet, the circuit of the magnet having been closed by the contacts on the transmitter. An important feature of this recorder is the arrangement whereby the movement caused by the armature being attracted to one magnet prepares the circuit of the other magnet until such a time as the bucket contact on the transmitter shall complete the circuit. Special means are also taken that the armature does not recoil after one movement, which would cause more than ·01 inch to be registered erroneously.

Exhibited by Messrs. NEGRETTI & ZAMBRA.

12 **Recording Rain Gauge.**

In this instrument the water-reservoir is so far below the surface of the ground that there is little fear of freezing. When the instrument records an inch of rainfall, the water siphons off and the pen thus automatically falls from one inch to zero in about 15 seconds.

Exhibited by Messrs. LANDER & SMITH.

13 **Popular Rain Gauge.**

The stem of the funnel passes to the bottom of a receiver which fits into a zinc jacket. The funnel is permanently attached to the receiver, which can be quickly emptied by means of a special outlet or spout. The glass receiver is graduated to enable the approximate amount of rainfall to be seen at a glance. *Exhibited by* Messrs. LANDER & SMITH.

14 **"Camden" Rain Gauge Measuring Glass.**

The lower part of the glass is conical, so as to enable the first ·01 inch to be distinctly subdivided. It also has a duplicate scale graduated on the back. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

Evaporation Gauges.

15 **Richard's Self-Recording Evaporation Gauge.**

The water contained in a closed reservoir is drawn up by a wick which is continually wetting a sheet of blotting-paper of a determined section and exposed to evaporation. A float transmits to the pen the height of the liquid. *Exhibited by* Messrs. J. LEVI & Co.

16 **Symons's Evaporation Tank, with Halliwell's Float and Index-Finger Gauge**

for readily reading the level of the water to ·01 inch or less. The tank exhibited is 4 feet square (though Symons's pattern measures 6 feet square), the comparative observations between tanks of different sizes at the Southport Observatory indicating, in Mr. Baxendell's opinion, that no appreciable gain results from the use of a larger tank, but that materially smaller ones are definitely inadmissible.

Exhibited by F. L. HALLIWELL.

Thermometers.

17 **Model of Metallic Thermograph.**
Made by the late Mr. N. S. Heineken in 1837.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

18 **Whitehouse's Experimental Thermograph,**
on Six's principle. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

19 **Richard's Thermograph.**
The thermometer consists of a very thin curved metal case (a Bourdon tube) containing alcohol, one end being a fixture and the other movable. As the alcohol expands or contracts with the changes of temperature it alters the curve of the tube, making it flatter or otherwise. The end of the tube communicates its motion by means of a metal rod to a lever carrying a pen, which marks a graduated paper wound on a cylinder. A clock turns the cylinder round once in seven days. (Three patterns are shown.) *Exhibited by* Messrs. J. LEVI & Co.

20 **Lander's Thermograph.**
Made with a compound strip of extraordinary sensitiveness to temperature, so that it gives a movement of nearly 1 inch for difference of 10° without the magnification of levers.
Exhibited by Messrs. LANDER & SMITH.

21 **Open Wound Thermometers for measuring Air Temperatures.**
These thermometers are of the electrical resistance type, devised by Callendar and Griffiths, the measurement being based on the change of resistance of a fine platinum wire with variation of temperature.
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT Co.

22 **Callendar Recorder**
Connected to one of the above thermometers, and recording continuously the temperature of the air outside the building. The recorder comprises a slide-wire Wheatstone Bridge, in one arm of which the resistance thermometer is placed, the balance of the Bridge being maintained automatically by the movement of a slider actuated by clock motors, which are controlled by a delicate relay in connection with the Bridge Galvanometer. The recording pen is directly carried upon the slider, and thus registers upon the drum the varying positions which the slider has to occupy in order to keep the Bridge balanced.
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT Co.

23 **Electrical Resistance Thermometer**
With protecting tube for measuring earth temperatures, connected to a Whipple Direct-Reading Temperature Indicator, giving temperatures on the Fahrenheit scale. The Indicator is essentially a combined Wheatstone Bridge and Galvanometer, the slide wire of the Bridge being wound helically upon a drum, and the readings taken from a scale which is likewise disposed helically upon a similar drum, which carries the galvanometer contact maker.
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT Co.

24 **Four Point Switchboard**
For connecting a series of thermometers to a Temperature Indicator.
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT Co.

25 **Thermometers used in the Scottish Antarctic Expedition.**
Thermometer used for taking sea temperatures.
Deep Sea Thermometer to withstand 8 tons pressure.
Ordinary Thermometer used in temperate zones.
Thermometer graduated to $-105°$.
Minimum Radiation Thermometer graduated to $-95°$.
Exhibited by W. S. BRUCE.

26 **Mercurial Thermometer graduated from $-50°$ to $+670°$.**
Formerly belonging to the late Mr. J. Glaisher, F.R.S.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

27 **Thermometers used by the National Antarctic Expedition, 1901-4.**
Exhibited by the METEOROLOGICAL COUNCIL.

28 **Instruments used in Sir J. C. Ross's Antarctic Expedition, 1839-43.**
Deep Sea Thermometer.
Herschel's Actinometer. *Exhibited by the* METEOROLOGICAL COUNCIL.

29 **Spirit Thermometers used in Arctic Expeditions.**
(1) H.M.S. *Assistance*, 1850-51; (2) H.M.S. *Resolute*, 1850-51; (3) Yacht *Fox*, 1857-59. *Exhibited by the* METEOROLOGICAL COUNCIL.

30 **Spirit Thermometer,**
one which is believed to have been used in Sir R. Collinson's Arctic Expedition, 1850-55, contrasting the maker's scale with the true scale at low temperatures. It has a box-wood scale. A paper scale pasted over the wood differs from the original graduations by about 30° at $-100°$. On recent verification at Kew, the reading in freezing mercury, instead of being $-37°\cdot9$, was found to be, on the paper scale, $-39°\cdot5$, and on the maker's scale $-58°$.
Exhibited by the NATIONAL PHYSICAL LABORATORY.

31 **Comparator.**
For comparing thermometers in a horizontal position.
Exhibited by the NATIONAL PHYSICAL LABORATORY.

32 **Hicks's Mercurial Minimum Thermometer.**
This thermometer was shown at the International Exhibition, 1862.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

33 **Richard's Recording Actinometer.**
This instrument records the indications of the Black and Bright Bulb Solar Radiation Thermometers. *Exhibited by* Messrs. J. LEVI & Co.

34 **Thermograph, English make.** *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

35 **Dawson's Telluradiometer.**
This instrument is something like a sensitive kind of differential thermometer with a bulb exposed to free radiation on a roughened black surface, and the other bulb protected from radiation by means of a thick covering of hard wood smoothed and enamelled white. Inside the stem, between the two bulbs, is an index which registers the maximum difference of temperature in the two bulbs. It also indicates the actual difference of the temperature of the two bulbs.
Exhibited by Messrs. LANDER & SMITH.

Barometers.

36 **Photographic Barograph.**
Kew pattern, in use at Fort William Observatory from 1890 to 1904.
Exhibited by the METEOROLOGICAL COUNCIL.

37 **Self-Recording Mercurial Barometer.**

Improved Milne's pattern. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

38 **Dines's Self-Recording Mercurial Barometer.**

The pen is actuated by a float in the lower cistern of the siphon barometer, the motion being multiplied by a lever so that a length of $1\frac{1}{2}$ inches on the paper may correspond to a change of 1 in. in atmospheric pressure. The float is in the form of a hollow cylinder sealed at the top and floating mouth downwards in the mercury.

A rise of temperature lowers the level of the mercury in the lower cistern, but at the same time it expands the air in the float, and makes it swim higher in the mercury. The volume of air is so adjusted that there may be a complete compensation. There is an additional pen fixed to the frame, which draws a line of reference on each sheet of paper while it is on the clock drum, and for accurate measurement this line is taken as the zero line, since by this means the error that might be caused by placing the chart unequally on the drum, or by an incorrect printing of the charts, is avoided.

Exhibited by J. J. HICKS, F.R.Met.Soc.

39 **Micro-Barograph, for the study of Minor Variations of Atmospheric Pressure.**

The instrument shows the details of comparatively rapid fluctuations of pressure. Variations of pressure are recorded by a lever which magnifies the vertical motion of an inverted cylinder floating, mouth downwards, on mercury. The interior of the cylinder is in communication with a sealed air chamber. The instrument is sensitive to variations of pressure and temperature. Minor variations of temperature are obviated by non-conducting material. The slow variations of temperature and of pressure are reduced to insignificance by a small leak between the chamber and the external air. The relatively rapid changes of pressure are clearly recorded.

The instrument was designed by Mr. W. H. Dines at the suggestion of the exhibitor. *Exhibited by* W. N. SHAW, F.R.S.

40 **Micro-Barograph or Differential Barograph.**

Its readings depend on the time rate of change of the barometer. It shows when the barometer varies rapidly, and takes no account of slow barometric changes. In principle it depends on the change of volume of air when the pressure changes, temperature remaining constant. In order to compensate slow pressure changes, the air vessel has a leak through a fine capillary tube, and in order to prevent rapid temperature changes affecting the readings, the vessel is bedded in cotton wool. The pressure-change draws out, or forces in, a thin indiarubber membrane, and the movements of this membrane are recorded by a lever of the type used in the Shaw and Dines' Micro-Barograph.

Exhibited by S. SKINNER, M.A.

41 **Richard's Barograph.**

This instrument consists of a series of vacuum boxes by which the effects of the atmospheric pressure are increased and transmitted by a system of levers to an arm carrying a pen. (Three patterns are shown.)

Exhibited by Messrs. J. LEVI & Co.

42 **Aneroidograph.**

Fitted with pen for drawing a base line and lever for making time marks.

Exhibited by the METEOROLOGICAL COUNCIL.

43 **Negretti and Zambra's Baro-Thermograph.**
This instrument combines in one apparatus the Recording Barometer and Recording Thermometer, giving thus on one and the same chart continuous records of the atmospheric pressure and temperature.
Exhibited by Messrs. NEGRETTI & ZAMBRA.

44 **Algué's Baro-Cyclonometer.**
This instrument consists of two parts, the first an aneroid barometer, the dial of which is fitted with a movable outer or concentric ring, having divisions on it indicating the four zones of the cyclone, with index mark for setting it. The other part of the instrument is the cyclone dial, which consists of a compass plate and a transparent storm disc to revolve over it. Mounted to work on the centre of these two discs are two pointers, one of which is divided on two-thirds of its radius into 100 parts, and the other carries at two-thirds of its radius a small secondary pointer. *Exhibited by* Messrs. H. HUGHES & SON.

45 **Richard's Barometer for measuring heights.**
Exhibited by Messrs. J. LEVI & Co.

46 **Richard's Self-Recording Barometer for great heights.**
The cylinder turns once in 6 hours.
Exhibited by Messrs. J. LEVI & Co.

47 **Richard's Self-Recording Statoscope.**
Exhibited by Messrs. J. LEVI & Co.

48 **Barograph, English make.** *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

49 **Richard's Spring Suspension.**
This can be fixed to the top of a cabin and used for carrying Richard's Recording Instruments, in order that they may not be affected by the motion of the vessel. *Exhibited by* Messrs. J. LEVI & Co.

Typical Station.

50 **Climatological Station.**
Enclosure with Instruments necessary for the equipment of a Climatological Station of the Royal Meteorological Society, viz.—
Stevenson Thermometer Screen, fitted with—
Dry Bulb Thermometer.
Wet Bulb "
Maximum "
Minimum "
Snowdon Rain Gauge and Measuring Glass.
Black and Bright Bulb Thermometers.
Grass Minimum Thermometer.
Campbell-Stokes Sunshine Recorder.
Earth Thermometer (1 foot).
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

Aeronautics.

51 **Instruments used by Mr. J. Glaisher, F.R.S., in his famous Balloon Ascents for the British Association, 1862-66.**
The instruments are placed in position on the board as used in the car of the balloon. They were mostly fastened by string, which could be readily cut before reaching the ground, and the instruments were then placed between pads in the basket to prevent breakage.

On September 5, 1862, the great altitude of about 7 miles from the earth was reached.

Exhibited by the Royal Meteorological Society.

52 **Statoscope for use in Balloons.**

This is a very sensitive atmospheric barometer.

Exhibited by Messrs. J. Levi & Co.

53 **"Ballon Sondes."**

Two small rubber Balloons.

Exhibited by P. Y. Alexander, F.R.Met.Soc.

54 **Kite with Meteorograph in Position.**

This kite with a short line will fly at an angular elevation of from 60° to 65°. With a good breeze it exerts a pull of 40 to 60 lbs., and will carry the meteorograph to a vertical height of over 8000 feet.

Exhibited by W. H. Dines, F.R.Met.Soc.

55 **Kite for Strong Winds (folded up).**

Exhibited by W. H. Dines, F.R.Met.Soc.

56 **Wire for Kite-flying.**

1. Sample of wire. Breaking strain 300 lbs.
2. Eye at end of wire.
3. Clamp for attaching supplementary kite to wire.

Exhibited by W. H. Dines, F.R.Met.Soc.

57 **Meteorograph.**

By M. Teisserenc de Bort, used at Crinan in August and September 1903. *Exhibited by* W. H. Dines, F.R.Met.Soc.

58 **Dines's Meteorograph.**

Used at Crinan in June and July 1904.

Exhibited by W. H. Dines, F.R.Met.Soc.

59 **Dines's Meteorograph, for use with Kites.**

Exhibited by J. J. Hicks, F.R.Met.Soc.

60 **Meteorograph used with Kite**

in the Scottish Antarctic Expedition.

Exhibited by W. S. Bruce.

61 **Kite Camera and Cage**

used in the Scottish Antarctic Expedition.

Exhibited by W. S. Bruce.

62 **Richard's Self-Recording Baro-Thermo-Hygrometer.**

This instrument is made in aluminium, and is for use with kites.

Exhibited by Messrs. J. Levi & Co.

63 **Hergesell's Baro-Thermograph for Ballon-sondes.** (Two patterns are shown.) *Exhibited by* J. & A. Bosch.

64 **Meteorograph in Cork Case and fixed in Basket for use with Kites.**

Exhibited by L. Teisserenc de Bort, F.R.Met.Soc.

65 **Meteorograph in Cork Case and fixed in Basket for use with Kites or Fixed Station.** *Exhibited by* L. Teisserenc de Bort, F.R.Met.Soc.

66 **Meteorograph for use with Ballon-sondes in Wicker Cage.**

The record by this instrument is made on smoked paper.

Exhibited by L. Teisserenc de Bort, F.R.Met.Soc.

67 **Altimeter.**

Aneroid barometer for registering the height to which kites and other aerial machines ascend.

Exhibited by J. J. Hicks, F.R.Met.Soc.

Hygrometers.

68 **Assmann's Aspiration Psychrometer.**

In this instrument a current of air is drawn over the bulbs of the dry and wet thermometers by means of a fan. (Two patterns are shown.)

Exhibited by R. FUESS.

69 **Self-Recording Dry and Wet Bulb Thermograph.**

Exhibited by Messrs. NEGRETTI & ZAMBRA.

70 **Self-Recording Hair Hygrometer.**

The recording portion is similar to that of the barographs and thermographs made by this firm. The actuating portion is a wisp of about a dozen hairs fastened at each end, and stretched laterally by a small weighted lever; the elongation and contraction of the hairs causes motion of the lever, and is thereby recorded on the cylinder.

Exhibited by Messrs. NEGRETTI & ZAMBRA.

71 **Richard's Self-Recording Dry and Wet Bulb Thermograph.**

This consists of a pair of thermometers, which are placed side by side; but they are curved reversely, and are placed as far apart as possible. The wet bulb thermometer is covered with muslin, and is kept moist by a water vessel below into which the muslin dips, and also by a capillary siphon from a second water vessel above.

Exhibited by Messrs. J. LEVI & CO.

72 [**Richard's Self-Recording Hair Hygrometer.**

Exhibited by Messrs. J. LEVI & CO.]

73 **Hygroscopes made of the Beard of the Wild Oat (Avena fatua).**

Extract from F. Cajori's *History of Physics*, 1899, p. 48:—"About the same time (middle of sixteenth century) Battista Porta [inventor of the Camera Obscura] called attention to the hygroscopic qualities of the beards of wild oats. He saw children paste to a beard small pieces of paper which would bend one way or another, according as the air was dry or moist. In the early part of the seventeenth century wild oats were used extensively as a hygroscopic substance."

Exhibited by R. INWARDS, F.R.Met.Soc.

Other Instruments.

74 **Cloud Camera.**

One of two used at Kew from 1884 to 1890 for the photographic measurement of cloud heights and velocities.

Exhibited by the METEOROLOGICAL COUNCIL.

75 **Besson's Nephoscope.**

This instrument consists of a long brass rod, mounted in a vertical position in such a manner that it can revolve freely, and bearing at its upper end a horizontal cross-piece provided with a number of vertical spikes. The observer places himself so that the cloud whose direction of motion is to be ascertained appears in the same straight line as the central spike, and then revolves the cross-piece until the cloud appears to move along the line of spikes, while the observer himself remains motionless. The direction in which the cross-piece is pointing is then read off on a graduated circle provided for the purpose. By observing the time taken for the cloud to pass from spike to spike the angular velocity can be determined. *Exhibited by* W. N. SHAW, F.R.S.

76 **Dankelmann's Hypsometer.** *Exhibited by* R. FUESS.

77 **Chronograph.** *Exhibited by* R. FUESS.

78 **Richard's Self-Recording Instrument for Earth Currents.**
Exhibited by Messrs. J. LEVI & Co.

79 **Anemoidograph**
for tracing the trajectories of air in cyclonic storms of certain well-defined types. The instrument can be set for various ratios between the velocity of the storm centre and that of the wind in the storm, and also for varying degrees of "incurvature." *Exhibited by* W. N. SHAW, F.R.S.

80 **Thermopsychrophorus.**
An apparatus illustrating the cooling effect by the communication of heat under certain conditions to a mass of air in the free atmosphere. Saturated air is contained in a wide-necked vessel, which dips into mercury. The vessel is supported on one arm of a balance, so loaded that the equilibrium is nearly neutral. On supplying heat to the enclosed air, by passing an electric current through a filament in the vessel, thermal expansion takes place under diminishing pressure, and cools the air sufficiently to form a cloud. The corresponding conditions in the free atmosphere arise when warmed air ascends.
Exhibited by W. N. SHAW, F.R.S.

81 **Elster and Geitel's Dissipation Apparatus.**
For determining the rate at which electricity is dissipated from a charged body exposed to the air. *Exhibited by* G. SIMPSON.

82 **Ebert's Aspiration Apparatus.**
For finding to what extent the air is ionized. *Exhibited by* G. SIMPSON.

83 **Apparatus for measuring the Amount of Radio-Active Emanation in the Atmosphere.** *Exhibited by* G. SIMPSON.

Anemometers.

84 **Original Model of Beckley's Self-Recording Anemometer.**
Exhibited at the Meeting of the British Association in 1856.
Exhibited by the NATIONAL PHYSICAL LABORATORY.

85 **Oxley's Pressure Plate Anemometer.**
The pressure with the corresponding direction are marked by a pencil on a slate disc. *Exhibited by the* METEOROLOGICAL COUNCIL.

86 **Dines's Pressure Tube Anemometer.**
Recording pattern. (See *Quarterly Journal*, vol. **18**, p. 165.)
Exhibited by R. W. MUNRO, F.R.Met.Soc.

87 **Combined Head, for complete Dines-Baxendell Anemograph.**
By this combination a single iron gas-pipe pillar suffices for both Dines's Recording Pressure Tube Anemometer and Baxendell's Recording Anemoscope. The new Pressure Plate too, can, if desired, be mounted on the same upright. *Exhibited by* J. BAXENDELL, F.R.Met.Soc.

88 **Dines's Pressure Plate Vane Head.**
The small holes on the face of the plate all communicate with an air space inside, and since the holes are all of exactly similar construction and size, the air pressure inside is very approximately the mean of the pressures on the elements of the face of the plate. There is a similar arrangement for the back of the plate, and a similar statement

applies to it. The difference of the pressure in the two air spaces multiplied by the area of the plate gives therefore the whole force produced by the wind normal to the face. This difference of pressure is measured, and recorded on the chart of an ordinary pressure tube anemometer. *Exhibited by* R. W. MUNRO, F.R.Met.Soc.

89 **Baxendell's Anemoscope or Wind Direction Recorder.**
For furnishing similarly *detailed* records of the variations of wind direction to those of the variations of wind velocity or pressure given by Dines's Pressure Tube recording Anemometer.
Exhibited by J. BAXENDELL, F.R.Met.Soc.

90 **Dines-Baxendell Non-oscillating Pressure Plate Maximum Anemometer.** *Exhibited by* F. L. HALLIWELL.

91 **Anemo-Cinemograph.**
This instrument indicates and registers the velocity of the wind in miles or metres per hour, directly and without any calculation.
Exhibited by Messrs. J. LEVI & Co.

92 **Portable Pressure Plate Anemometer.**
Working Model. This instrument has been designed to register automatically the force and direction of the wind at any given time, the former by means of a vertical pressure-plate kept facing the wind by an ordinary vane mounted on ball bearings. Its horizontal movements actuate a spiral spring-balance to which is attached a metallic pencil, marking the variations of pressure (in pounds per square foot) upon a chart placed round a clock cylinder which revolves once in 24 hours. The pressure-plate may be allowed to vibrate freely or it can be adjusted to indicate maximum pressure only. The direction of the wind is registered on the same chart by means of a spiral marker coiled round a cylindrical drum attached to the end of the vane shaft. The apparatus is complete in itself, and is so constructed that it can be readily fixed either on the top of a building or on the ground. Designed and constructed by Jas. B. Jordan.
Exhibited by Messrs. NEGRETTI & ZAMBRA.

93 **Robinson Anemometer used by the National Antarctic Expedition,** while in the *Discovery's* winter-quarters, 1902-3.
Exhibited by the METEOROLOGICAL COUNCIL.

94 **Richard's Anemometer or Current Meter.**
Exhibited by Messrs. J. LEVI & Co.

95 **Richard's Self-Recording Anemometer.**
This instrument records electrically to 16 directions.
Exhibited by Messrs. J. LEVI & Co.

96 **Anemometer Head and Wind Vane**
used at the winter-quarters of the National Antarctic Expedition, 1902-4. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

97 **Negretti & Zambra's Recording Anemometer.**
The cups, arms, and gearing are identical with those used in the Robinson Dial Anemometers, and the motion imparted to this gear by cups is transmitted to a wheel carrying a perfect helix. The lever arm which carries the pen is gradually raised by the motion of this helix until 100 miles have been registered; when this spot is reached the lever falls to the other end of the helix, the recording pen descends to zero and begins to record a second 100 miles.

A small plunger working in a cylinder filled with glycerine prevents the arm from falling too suddenly and from upsetting the ink in the pen. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

98 **Negretti & Zambra's Electrical Recording Anemometer.**

The transmitter, placed at the spot at which the velocity is to be determined, is made with the usual Robinson's cups, arms, and gear, and with two tumblers which impinge on a tilting arm at every mile. On either end of this arm are fitted contacts, and every time that the arm tilts over, the contact at this end closes and completes an electrical circuit. The contacts in this transmitter are made by the dipping into mercury of platinum wires of sufficient length to give an absolutely certain contact by guarding against corrosion or oxidisation.

The recorder is constructed on the principle of an escapement motion attached to a perfect helix, which raises the lever arm and pen by steps of 1 mile until 100 miles have been covered, when the pen descends steadily and is ready to commence again. The escapement is set in motion by the attraction of an armature to an electro-magnet, the circuit of the magnet being completed by the contacts on the transmitter. An important feature of this recorder is the arrangement whereby the movement caused by the armature being attracted to one magnet prepares the circuit of the other magnet until such a time as the arm contact on the transmitter shall complete the circuit. Special means are also taken that the armature does not recoil after one movement, which would cause more than 1 mile to be registered erroneously. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

99 **Lander's Anemometer.**

This Anemometer is an instrument in which the wind blowing against the open mouth of a tube, which is kept facing the wind, exerts a pressure which is conducted down a tube or series of tubes fixed together by unions, and thence by means of a mercury joint and flexible tubing to the interior of a thin bellows so delicately counterpoised, that it rises with the faintest breeze. Attached to a disc or plate of the bellows is a lever carrying a pen which records on a drum revolved by clockwork. The lever is weighted by means of a small cone which floats in a vessel of glycerine, the density of which is adjusted to allow the conical float to almost sink. When the float thus lies in the glycerine it has no weight, but when lifted up by the wind the weight gradually increases until it is lifted completely above the surface of the liquid.

The lower end of the tube near the mercury joint is removable, and is wrapped around with a chart on which is recorded the direction of the wind by means of a pen, which is allowed to slowly slide down a brass bar at the same rate as the drum revolves with the pressure record. *Exhibited by* Messrs. LANDER & SMITH.

100 **"Opsilus" Anemometer.**

The apparatus consists of a head or vane, which is fixed high on a roof or other prominent situation, and an indicator which is placed in any desired position, such as a window, a drawing-room, or a pier-head, or in any public building, etc. The two parts are connected together by means of a single small flexible lead tube.

The head, strongly made in gun-metal, is fitted with a ball bearing, and is delicately counterpoised so that it turns with the faintest movement of the air, and thus, whatever the variation of the direction of the wind, it always presents the aperture (through which the pressure is transmitted to indicator) to the current. Just below the head is a

mercury joint, so that the entire pressure of the wind upon the open mouth or orifice of the head is conducted without loss down the tube to the indicator, and enables the head to turn to the wind with a minimum of friction. All the parts in contact with the mercury are solidly made in iron. *Exhibited by* Messrs. LANDER & SMITH.

101 **"Lowne" Electrical Recording Vane and Anemometer.**
The instrument denotes eight points of the compass, and requires only five small insulated wires laid from the outdoor transmitter to the indoor dial. The outdoor transmitter is absolutely weather-proof, and is contained in a metallic case placed within a strong cast-iron box, which supports a cast-iron pedestal carrying the movable parts of the vane. *Exhibited by* R. M. LOWNE.

102 **Higham's Electrical Wind Indicator.**
Consists of a vane revolving on a steel spindle, the extra weight of the tail of vane being sufficient to form contact round a small commutator on the spindle. The commutator plates are connected to an electro-magnet indicator by a small 8 wire cable, and showing 16 points of the compass. *Exhibited by* J. J. HICKS, F.R.Met.Soc.

103 **Dales's Anemograph.** *Exhibited by* C. DALES, F.R.Met.Soc.

Sunshine Recorders.

104 **Wooden Bowl for Sunshine Recorder.**
Campbell's first form, 1853. Royal Observatory, Greenwich.
Exhibited by the ASTRONOMER-ROYAL.

105 **Wooden Bowl formerly used for recording Sunshine.**
Exhibited by the METEOROLOGICAL COUNCIL.

106 **Gypsum Bowl for Sunshine Recorder.**
Campbell's design about 1878. *Exhibited by the* ASTRONOMER-ROYAL.

107 **Gun-metal Bowl with Ball.**
In use at the Royal Observatory, 1876-1886.
Exhibited by the ASTRONOMER-ROYAL.

108 **Discarded Ball, showing Deterioration in Transparency.**
In use at the Royal Observatory, 1887-1896.
Exhibited by the ASTRONOMER-ROYAL.

109 **Defective Campbell-Stokes Sunshine Recorder.**
This instrument was formerly in use at the Royal Botanic Gardens, Regent's Park, but had to be discontinued in 1900 owing to the glass ball having become deteriorated through atmospheric action, and so failing to record the proper amount of sunshine.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

110 **Campbell-Stokes Sunshine Recorder (Curtis's Pattern).**
This instrument is provided with simple arrangement for adjusting the glass ball; it is also adjustable for use in any latitude.
Exhibited by J. J. HICKS, F.R.Met.Soc.

111 **Campbell-Stokes Sunshine Recorder.**
Constructed with fixed frame for use at a given latitude.
Exhibited by Messrs. NEGRETTI & ZAMBRA.

112 **Campbell-Stokes Sunshine Recorder for use at various Latitudes, with a range of 10°.**

This is a modification of the universal type, the zodiacal frame being identical with the original pattern, and the crown glass ball is supported top and bottom and clamped in position. It is only by adopting this principle that the instrument may be constructed for latitudes in the region of the Equator, as the separate support for the ball would be impracticable. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

113 **Sunshine Recorders used by the National Antarctic Expedition** while in the *Discovery's* winter-quarters, 1902-3. The instruments are constructed so as to give continuous records for twenty-four hours.
Exhibited by the METEOROLOGICAL COUNCIL.

114 **Jordan's Sunshine Recorder.**

This instrument consists of a cylindrical box, on the inside of which is placed a strip of cyanotype paper. Sunlight being admitted into this box by two small apertures, is received on the paper, and travelling over it by reason of the Earth's rotation, leaves a distinct trace of chemical action. (Two patterns are shown.)
Exhibited by Messrs. NEGRETTI & ZAMBRA.

115 **Jordan's Sunshine Recorder, Twin Pattern.**

The improvement in this instrument over the former consists in using two hemi-cylindrical boxes, one to contain the morning and the other the afternoon record. An aperture for admitting the beam of sunlight is placed in the centre of the rectangular side of each box, so that the length of the beam within the chamber is the radius of the cylindrical surface on which it is projected ; its path, therefore, at all seasons follows a straight line on the paper. The hemi-cylinders are placed with their diametral planes at an angle of 60°. (Two patterns are shown.)
Exhibited by Messrs. NEGRETTI & ZAMBRA.

116 [**M'Leod's Photographic Sunshine Recorder.**

This instrument consists of a glass sphere silvered inside and placed before the line of a camera, the axis of the instrument being placed parallel to the polar axis of the Earth. The light from the sun is reflected from the sphere, and some of it passing through the lens forms an image on a piece of cyanotype paper within the camera. In consequence of the rotation of the Earth the image describes the arc of a circle on the paper, and when the sun is obscured this arc is broken.
Exhibited by THE NATIONAL PHYSICAL LABORATORY.]

117 **Dawson-Lander Sunshine Recorder.**

This instrument consists of a small outer cylinder of copper which revolves with the sun, and through the side of which is cut a narrow slit to allow the sunlight to impinge on a strip of sensitive paper wound round a drum, which fits closely inside the other cylinder, but which is held by a pin so that it cannot rotate. The paper being in direct contact with the aperture, no great accuracy is necessary in setting the instrument, as the only thing affecting the record is the movement of the slit independently of the paper.

Diffused light is prevented from reaching the sensitive paper by means of a flattened funnel-shaped hood fitted in front of the slit.

The instrument is adapted for giving automatically a continuous record for a week, a month, or any required period. By means of a screw fixed to the lid of the outer cylinder, the drum holding the sensitive paper is made to travel endwise down the outer tube an

eighth of an inch daily, so that a fresh portion of the sensitive surface is brought into position to receive the record.

Exhibited by Messrs. LANDER & SMITH.

118 **Sunshine Receiver for use with Callendar Electric Recorder.**
The Receiver consists of two lengths of fine platinum wire of equal resistance, both wound zig-zag and disposed side by side in one plane. One length is embedded in black enamel, the other is bright and uncovered. A glass bulb filled with dry air encloses both coils. The intensity of the sunshine is measured by the difference of resistance between the embedded wire and the bare wire.

Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

119 **Richard's Photographic Sunshine Recorder.**
This apparatus consists of a cylinder with an aperture in the form of a very long V, and turning with the sun once in 24 hours before a sensitive paper. The sunshine is indicated by a blue trace and the character of the light by the intensity of the trace.

Exhibited by Messrs. J. LEVI & Co.

120 **Richard's Photographic Sunshine Recorder with Multiple Tubes.**

Exhibited by Messrs. J. LEVI & Co.

Section II.

LIGHTNING.

Objects Struck by Lightning.

121 **Clothes of Man struck by Lightning**
near Cardiff, July 17, 1903. (See *Q. J. Roy. Met. Soc.* **31,** 1905, p. 55.)

Exhibited by J. LYNN THOMAS, C.B.

122 **Boots of Man struck by Lightning.**

Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

123 **Model of Chimney Shaft fitted with Lightning-Conductors.**

Exhibited by Messrs. J. W. GRAY & SON.

124 **Damaged Lightning-Conductors.**

1. Two sets of points showing effect when a lightning-conductor in good order is struck by lightning.

2. Piece of copper rope conductor through which lightning passed after causing damage to Stradbroke Church, Eye, Suffolk.

3. Piece of woven wire conductor from German Lutheran Church, Dalston, damaged by lightning, March 1901.

Exhibited by Messrs. J. W. GRAY & SON.

125 **Damage by Lightning.**

1. Piece of tree destroyed by lightning at Chigwell, Essex, March 6, 1901.

2. Piece of a gate-post in North Road, Hainault, Essex, destroyed by lightning, April 7, 1902. *Exhibited by* Messrs. J. W. GRAY & SON.

126 **Model of Hedges's "Air to Earth System" of Lightning-Conductors.**
Exhibited by the GENERAL ELECTRIC Co., LTD.

127 **Portion of Tree damaged by Tornado**
in Wiltshire, October 1, 1899.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

Section III.

DRAWINGS, PHOTOGRAPHS, Etc.

Portraits.

128 **Marble Bust of James Glaisher, F.R.S.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

129 **Portrait of George James Symons, F.R.S.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

130 **Meteorological Breakfast, Southport, September 1903.**
This gathering took place during the meeting of the British Association.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

Meteorological Phenomena.

131 **Sky and Cloud Effects in the Antarctic Regions.**
Water-colour drawings made during the National Antarctic Expedition:— 1. Sunset from *Discovery's* Winter-Quarters; 2. Sunrise from *Discovery's* Winter-Quarters; 3. The *Discovery* in Winter-Quarters; 4. The *Discovery* in Winter-Quarters; 5. Midnight in February, Last Sight of Mount Discovery; 6. Sunrise on Western (Royal Society) Range; 7. Moonlight, M'Murdo Strait; 8. Possession Islands, Ross Sea; 9. Discovery Hut, M'Murdo Strait; 10. Sunlight on Western Range; 11. Iceberg off Cape Adare; 12. Sunlight on Mount Erebus' Smoke; 13. Ross's Great Ice Barrier. 14. Erebus Islets. 15. Ice-cliffs of Ross's Barrier. 16. Sunset in M'Murdo Strait. 17. Iceberg off Cape Adare. 18. Hut Point, A Grey Day.
Exhibited by Dr. E. A. WILSON.

132 **Cloud Photographs.**
Exhibited by Capt. D. WILSON-BARKER, F.R.Met.Soc.

133 **Photographs of Clouds**
taken with the Cloud Cameras at the Kew Observatory for determining the height of clouds. *Exhibited by the* METEOROLOGICAL COUNCIL.

134 **Photographs of Clouds**
taken in New Zealand, 1898.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

135 **Cloud Photographs.** *Exhibited by* F. DRUCE, F.R.Met.Soc.

136 **Cloud Photographs.** *Exhibited by* H. S. HAWORTH, F.R.Met.Soc.

137 **Photographs of Types of Lightning Flashes and of Lightning Spectra.**
The types here shown contain examples secured with fixed and moving cameras. Other examples illustrate results produced by peculiar photographic action (such as "dark" lightning) and to instrumental errors (camera out of focus; "rope" lightning).
Exhibited by Dr. W. J. S. LOCKYER.

138 **Damage by Lightning.**
Map showing the position and nature of damage caused by lightning in England and Wales, 1898-1903, compiled by A. Hands, F.R.Met.Soc.
Exhibited by Messrs. J. W. GRAY & SON.

139 **Photographs of Damage by Lightning.**
(1) Godshill Church, Isle of Wight; (2) Cold Overton Church; (3) Swanscombe Church; (4) Southborough Vicarage; (5) Colleyweston Church; (6) Islip Church; (7) Prince of Wales Inn, Bradley; (8) Hallingbury Church; (9) Bradley Congregational Church; (10) Cowden Church; (11) St. Gabriel's Church, Cricklewood; (12) Little Staughton Church; (13) Cottage at Whatton, near Grantham; and (14) Tree charred by lightning, on the under cliff, Isle of Wight.
Exhibited by Messrs. J. W. GRAY & SON.

140 **Damage by Lightning.**
Drawings and Photographs collected by the Lightning Research Committee. *Exhibited by* K. W. HEDGES, M.Inst.C.E.

141 **Snow Crystals observed by J. Glaisher, F.R.S., 1855.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

142 **Two Photographs showing Effect of Frost at the Pierhead, Southport, February 1895.** *Exhibited by* J. BAXENDELL, F.R.Met.Soc.

143 **Niagara in Summer and Winter.**
A collection of 46 views. *Exhibited by* W. ELLIS, F.R.S.

Instruments.

144 **[Halliwell's Anemoclinograph.**
Drawing of latest pattern for accurately recording minute angular deviations of wind movement from a horizontal path, or from one parallel to the surface of the ground. *Exhibited by* F. L. HALLIWELL.]

145 **Halliwell's Improved Float Pattern Pluviograph.**
Diagram showing working details of self-recording Rain Gauge, 1905 pattern, and specimen daily records. *Exhibited by* F. L. HALLIWELL.

146 **Dines's Ether Thermograph.**
Drawing of Halliwell's 1905 design. *Exhibited by* F. L. HALLIWELL.

147 **Denza's Anemograph and Pluviograph,**
employed at the Stations of the Italian Meteorological Association.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

148 **Photographs of the first "Ballon-sondes" employed in America,**
with a table of the heights and temperatures recorded by them.
Exhibited by A. L. ROTCH, F.R.Met.Soc.

149 **Drawings and Photographs of Mr. S. P. Fergusson's new instrument**
for recording the Time of Rainfall, and improved automatic recorder for Cloudiness at night in the neighbourhood of the Pole-star.
Exhibited by A. L. ROTCH, F.R.Met.Soc.

150 **Diagram showing method of burying Earth Thermometers.**
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

151 **Meteorological Exhibition, Southport, September 1903.**
Arranged in connection with the meeting of the British Association and of the International Meteorological Committee.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

152 **Exhibition of Anemometers, March 1882.**
This Exhibition was arranged by the Royal Meteorological Society in the Library of the Institution of Civil Engineers.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

153 **Photograph of the Tower of the Winds, Athens.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

Records.

154 **Registers taken with the Self-recording Instruments at a Station of the First Order.**
Falmouth, February 22-23, 1903.
Exhibited by the METEOROLOGICAL COUNCIL.

155 **Barograms and Thermograms.**
1. A normal day.
2. During cyclonic disturbance.

Exhibited by the METEOROLOGICAL COUNCIL.

156 **Barograms and Thermograms.**
1. Barometric changes due to atmospheric waves connected with the Krakatoa eruption, 1883.
2. Barograms during the period of eruptions of Mont Pelée and La Soufrière, May 4-11, 1902.
3. Barometric and thermometric changes at Oxford whilst the severe storm of February 26-27, 1903, was in progress in Ireland.
4. Barogram and thermogram during a gale with sudden squalls on March 27-28, 1903. *Exhibited by* Dr. A. A. RAMBAUT, F.R.S.

157 **Records of Dines's Pressure Tube Anemometers on various occasions of interest.** *Exhibited by the* METEOROLOGICAL COUNCIL.

158 **Barograph, Electrometer, Thermograph, and Osler Anemometer Registers,**
Royal Observatory, Greenwich, February 19-20, 1905, showing effect of squall at 3.30 P.M. on the 19th.
Exhibited by the ASTRONOMER-ROYAL.

159 **Thermograph Registers,**
Royal Observatory, Greenwich, March 8-9, April 19-20, October 17-18, December 11-12, 1904; and January 1-2, 1905.
Exhibited by the ASTRONOMER-ROYAL.

160 **Osler and Robinson Anemometer Registers,**
Royal Observatory, Greenwich, December 29-30, 1904; showing ordinary and large time-scale records for Osler.
Exhibited by the ASTRONOMER-ROYAL.

161 **Osler Pluviometer Register,**
July 25-26, 1904; and Thermograph Registers, July 25-26, August 4, and July 9-10, 1904.
Exhibited by the ASTRONOMER-ROYAL.

162 **Typical Sunshine Records,**
Royal Observatory, Greenwich, January 25, March 20, May 30, 1899.
Exhibited by the ASTRONOMER-ROYAL.

163 **Sunshine Diagrams**
obtained by the M'Leod Photographic Sunshine Recorder.
Exhibited by the NATIONAL PHYSICAL LABORATORY.

164 **Meteorological Records obtained with Callendar Recorder.**
Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

165 **Wind Records.**
Records for the same day, from two neighbouring Anemoscopes, one having its Vane excellently, and the other only tolerably, well exposed, showing the relatively great gustiness of the wind in the latter case.
Exhibited by J. BAXENDELL, F.R.Met.Soc.

166 **Traces obtained from Meteorograph**
during the Kite Experiments carried out by the Joint Committee of the Royal Meteorological Society and of the British Association.
Exhibited by W. H. DINES, F.R.Met.Soc.

167 **Electrograms.**
1. Diurnal variation on normal day, April 18-20, 1904.
2. Negative potential during passing showers, February 25-27, 1903.
3. Rapid oscillations during thunderstorm on afternoon and evening of July 19, July 19-21, 1903.
4. Negative and varying potential during steady rain, followed by high positive potential during fog, March 9-11, 1903.

Exhibited by the METEOROLOGICAL COUNCIL.

168 **Seismograms**
from the Milne Horizontal Pendulum at Kew. The origins assigned to the Earthquakes by Prof. Milne are as follows:—
Sept. 22. Off the Chinese coast.
Sept. 23. (Guatemala earthquake) Caribbean Sea.
Nov. 21. Off the Chinese coast.
Dec. 12. Unknown.
Exhibited by the NATIONAL PHYSICAL LABORATORY.

169 **Barograph Records taken on board the "Scotia."**
From Coats Land, 74° 1′ S., 22° 0′ W. to Gough Island, 40° 22′ S., 5° 45′ W. *Exhibited by* W. S. BRUCE.

170 **Observatories of the Scottish Antarctic Expedition.**
1. Omond House, Scotia Bay, South Orkneys.
2. Copeland Magnetic Observatory and Observation Cairn.

Exhibited by W. S. BRUCE.

Special Investigations.

171 **Automatic Records from various Observatories**
showing the changes in the meteorological elements during the passage across the British Isles of a deep cyclonic disturbance—February 26, 1905. *Exhibited by the* METEOROLOGICAL COUNCIL.

172 **Diagrams showing the comparison of estimated Wind Forces with Wind Velocities.**
The ordinates represent wind forces (Beaufort scale) and the abscissæ wind velocities in miles per hour recorded by anemometers at Scilly, Holyhead, and Fleetwood. The numbers inscribed in circles indicate

the number of times the wind velocities corresponding to the abscissæ of the circles were recorded on the occasions of wind forces corresponding to their ordinates. *Exhibited by the* METEOROLOGICAL COUNCIL.

173 **Diagram showing result of Earth Temperature Measurements** made at the Radcliffe Observatory, Oxford.

Exhibited by the CAMBRIDGE SCIENTIFIC INSTRUMENT CO.

174 **Diagram showing the Monthly Variation of the Temperature of the Ground at Different Depths,**

as determined by platinum resistance thermometers compared with the air temperature (in shade), 4 ft. above the surface.

Exhibited by Dr. A. A. RAMBAUT, F.R.S.

175 **Curves to illustrate the behaviour of the Short Period (about four years) Barometric Variation over the Earth's Surface, and its Relation to Rainfall.**

This is an investigation that is in progress at the Solar Physics Observatory, South Kensington. It has been found that while one portion of the Earth (Diagram 1) is experiencing excess high pressure conditions for some years, the antipodal portion (Diagram 2) is experiencing excess low pressure conditions simultaneously. A comparison of these two main types of pressure changes is shown in Diagram 3. Areas bordering on these two regions exhibit an intermediate type (Diagram 4). Some striking examples of opposite types, or barometric see-saws, are given in Diagram 5. The distribution of these types over the Earth's surface is shown in the map of the world (Diagram 6).

The short-period barometric change dominates the rainfall from year to year, and some curves are shown to illustrate this (Diagrams 7 and 8).

Exhibited by Dr. W. J. S. LOCKYER.

176 **Diagrams showing the Development and Metamorphosis of the superior and the inferior Tangential Bows of the Halo of 22°.**

These eleven drawings exhibit the shapes assumed by the superior and the inferior tangential bow of the halo of 22° with increasing height of the sun or the moon. The halo itself is always represented by the circle on each drawing, whose centre is to be sought, occupied by the sun or moon. For $H = 0°$ (H = sun's or moon's height above horizon) the two bows are of the same shape. With increasing height, both the superior and inferior bows lower their branches, and so become successively of the shape shown in the drawings for $H = 5°$ and $H = 10°{\cdot}55'$, the latter being the half of the radius of the halo. The inferior bow remains under the horizon, and is therefore invisible if the observer does not choose his observing point on a favourable mountain top. The photograph of the pointed form of the halo was taken from the top of the Sönnblick (10,170 ft.) in 1902. With further increasing height, the two branches of the inferior bow begin to cross one another and to form a loop, one phase of which is shown in the annexed photograph, taken also on the top of the Sönnblick. With the height still increasing, the branches of the inferior bow have entirely changed their positions ($H = 25°\ 2'$), and then begin to open anew, and with $H = 29°\ 15'$ touch the ends of the continually lowering branches of the superior bow. Finally, the height increasing more and more, the two bows form a veritable surrounding halo of the halo of 22°.

The plotted lines indicate that these parts of the branches are not likely to be seen, because of their feeble light.

Exhibited by Dr. J. M. PERNTER.

Early Weather Maps.

177 **First printed Daily Weather Map.**
Issued at the Great Exhibition, Hyde Park, August 1851.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

178 **Prospectus of the Daily Weather Map Company (Limited).**
This Company was formed for the purpose of raising capital to carry on the publication of the *Daily Weather Map.* The capital was to be £4000 in 400 shares of £10 each. Two maps were printed, viz., those for August 5 and September 3, 1861. The former map is printed at the back of the prospectus, but that for September 3 is shown.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

Pictorial Weather Forecasts.

179 **"The Daily Graphic" Illustrated Weather Forecast,**
which appears in that Journal every morning.
Exhibited by the EDITOR OF "THE DAILY GRAPHIC."

180 **"The Daily Chronicle" Illustrated Weather Forecast,**
which appears in that Journal every morning.
Exhibited by the EDITOR OF "THE DAILY CHRONICLE."

Climatic Diagrams and Maps.

181 **Meteorological Table by B. Woodcroft.**
The observations of the thermometer and barometer extended over a period of 80 years (1862).
Exhibited by Messrs. NEGRETTI & ZAMBRA.

182 **Diagram exhibiting the Climatological Data**
from stations in three districts of Great Britain, classified according to six Types of Weather.

The weather of each day during the periods dealt with was assigned to one of the following types:—

1. Gradient favourable for S.E. winds.
2. " " S.W. "
3. " " N.W. "
4. " " N.E. "
5. Conditions cyclonic, winds variable.
6. " anticyclonic, " "

The averages of the various elements for the days of each type are shown graphically for each station in a convenient form for comparison.
Exhibited by the METEOROLOGICAL COUNCIL.

183 **Synoptic Charts illustrating the Passage across the British Isles of a Cyclonic Disturbance**
for every two hours during the period from 8 A.M. March 24 to 8 A.M. March 25, 1902, with diagrams showing the trajectories of surface air within the area of the storm.
Exhibited by the METEOROLOGICAL COUNCIL.

184 **Rainfall Maps of the British Isles.**
1. Mean Annual Rainfall, 1870-1899.
2. Rainfall of Wettest Year, 1872.
3. Rainfall of Driest Year, 1887.

Exhibited by Dr. H. R. Mill, F.R.Met.Soc.

185 **Maps of Great Britain and Ireland showing Rainfall Stations at work in 1903,**
the records of which are reported in *British Rainfall.*

Exhibited by Dr. H. R. Mill, F.R.Met.Soc.

186 **Rainfall Chart of India.**
Compiled by H. F. Blanford, F.R.S.

Exhibited by the Royal Meteorological Society.

187 **Diagram showing the mean Prevalence of Gales.**
The curves of the gales on the coasts of the British Islands at various times in the year are drawn from five-day means, based upon records extending over the 30 years 1871 to 1900.

Exhibited by F. J. Brodie, F.R.Met.Soc.

188 **Isobaric Charts showing extremely High and Low Atmospheric Pressures over the British Isles.**
1. High, January 28, 1905.
2. Low, December 8, 1886.

Exhibited by the Royal Meteorological Society.

189 **Large Diagrams showing Temperatures observed in various Parts of the World.**
1. Highest and Lowest Temperatures.
2. Mean Annual Temperature.

Exhibited by the Royal Meteorological Society.

ADDENDA

190 **Redier's Barograph.**
A differential clock train causes a siphon barometer, by action from its float, to be kept in continual very slight vertical oscillation. When the atmospheric pressure is changing, the motion in one direction preponderates, and actuates a pencil.

Exhibited by Dr. H. R. Mill, F.R.Met.Soc.

191 **Self-Recording Mercurial Barometer.**
This instrument somewhat resembles, in construction, the old wheel barometer, but the float instead of rotating a wheel carries a pen which records directly on the drum. Instead of having both ends of the tube of the same bore, the upper end is made a cistern 10 times the area of the lower or short end, in which there is therefore 10 times more movement of the mercury than in the cistern. The float works in a bath of oil floating on the mercury, and is so arranged as to move almost without friction. The bore of the tube is $\frac{5}{16}$ inch throughout, thus allowing the mercury to move very freely.

Exhibited by Messrs. Lander & Smith.

192 **Piesmic Barometer.**
Air, when the barometer is low, is more compressible than when it is high. In the Piesmic Barometer, a tubeful of air is taken at atmospheric pressure, and its compressibility is tested by allowing mercury to run down the tube and compress the air inside. The depth to which the mercury descends varies with the compressibility of the enclosed air, and, therefore, also with the barometric pressure at the time. The reading of the scale gives the atmospheric pressure in inches of mercury.
Exhibited by F. DARTON & Co.

193 **Phillips's Maximum Thermometer.**
This is the original thermometer made by Prof. Phillips himself in 1832. *Exhibited by* J. J. HICKS, F.R.Met.Soc.

194 **Maximum and Minimum Thermometers.**
Used in Sir J. C. Ross's Antarctic Exhibition, 1839-43.
Exhibited by J. J. HICKS, F.R.Met.Soc.

195 **Improved Cylinder and Clockwork Movement.**
For recording instruments. *Exhibited by* Messrs. NEGRETTI & ZAMBRA.

196 **Funnel of 5-in. Rain Gauge.**
The Gauge was in use for many years at the Stye, Cumberland, where the average rainfall is about 170 ins. In the Funnel is inserted a portrait of the late G. J. Symons, F.R.S.
Exhibited by Dr. H. R. MILL, F.R.Met.Soc.

197 **Russian Kite for Meteorological Purposes.**
Exhibited by W. H. DINES, F.R.Met.Soc.

198 **Air Meter.**
Exhibited by R. M. LOWNE.

199 **Model of New and Simple Form of Sun Dial.**
Exhibited by J. B. JORDAN.

200 **Graduated Scale for measuring Sunshine Cards.**
Exhibited by Messrs. NEGRETTI & ZAMBRA.

201 **Records from the Jordan Sunshine Recorder.**
Exhibited by Messrs. NEGRETTI & ZAMBRA.

202 **Sunshine Records from the Antarctic Regions.**
Records for three consecutive days, viz. December 15-17, 1903, each showing a continuous record of 24 hours' sunshine.
Exhibited by the METEOROLOGICAL COUNCIL.

203 **Meteorological Changes at Selected Observatories**
during the passage of a Cyclonic Storm, February 26-28, 1903.
Exhibited by the METEOROLOGICAL COUNCIL.

204 **Barogram at Oxford, February 15, 1905.**
This shows a remarkable depression of short duration at 6.40 p.m.
Exhibited by Dr. A. A. RAMBAUT, F.R.S.

205 **"To-day's Weather."**
Weather Maps of North-west Europe at 8 a.m. were posted up each day in the Exhibition. *Exhibited by the* METEOROLOGICAL COUNCIL.

OBSERVATIONS AT CRINAN IN 1904, AND DESCRIPTION OF A NEW METEOROGRAPH FOR USE WITH KITES.

By W. H. DINES, B.A., F.R.S.

[Read April 19, 1905.]

In February 1904 I gave an account to this Society of the work of investigation of the upper air at Crinan in the preceding summer. Owing to various circumstances the observations then obtained were neither numerous nor consecutive, and it seemed desirable, if possible, to supplement them. This was rendered possible by the kindness of the Lords Commissioners of the Admiralty, who provided a very convenient vessel, the *Seahorse*, from June 17 to July 29, 1904, and kites were sent up with self-recording instruments attached, almost daily from her deck. The only breaks that occurred were from July 9 to 12 inclusive, while the vessel was away coaling; on Sundays; and on two days when a dead calm prevailed, and the speed of the vessel alone was found to be incapable of maintaining a kite.

Some modification of the apparatus has been found advisable, but the only part that calls for special notice is the meteorograph. During the first summer self-recording instruments made by MM. Richard Frères and costing £20 were used. These instruments were lost by falling into the sea on August 26, 1902, fortunately at the end of the period. The Joint-Committee of this Society and of the British Association are not so well off for funds that they can afford many such losses, and the instruments were not replaced. In 1903 Mons. Teisserrenc de Bort very kindly supplied us with two meteorographs, at a much smaller cost, one of which was lost on September 4, 1903, the other being still in the possession of the Committee. It was felt that it would be better, if possible, to obtain in England some cheaper form of instrument suitable for the purpose. It is, of course, essential that accurate observations should be made; and considering the time and trouble incurred in making systematic kite ascents, it would be very bad policy to sacrifice accuracy to cheapness. With apparatus for which there is not much demand, and where, consequently, prices are not reduced by competition, simplicity of design is a point not considered by either the designer or the maker; and yet simplicity is often of great value for its own sake, and a cheaper instrument may often be a better instrument, provided that cheapness is not secured by bad workmanship in the essential parts. In England scientific investigation does not meet with much encouragement, save by those immediately interested; and whereas for many years in foreign countries considerable sums of money have been set apart for the investigation of the upper air by the Government, here we have had to depend on contributions from societies and private individuals, and it has been necessary to cut down in every possible way the cost of the apparatus.

Last summer's work has shown that the meteorograph made by Mr. J. J. Hicks is capable of giving quite satisfactory results, and the price is such that the loss of one instrument is not of serious consequence; in fact, the meteorograph and the kite that carries it both cost between two and three pounds.

Description of Meteorograph.

The pens write on a disc of paper 11 inches in diameter instead of on a drum. The paper lies flat on a piece of thin wood, and turns about a pin passing through its centre. It is driven by contact near its circumference with a small milled wheel, which is driven in its turn by a clock. A roller mounted on a spring on the other side presses the paper against the milled wheel, and ensures sufficient friction. The pens describe arcs of circles on the paper disc, the chords of the arcs being roughly coincident with radii of the disc. It will thus be seen that the time scale being angular is not uniform, but depends on the position of the pen. (Fig. 1. Trace obtained on July 21, 1904.)

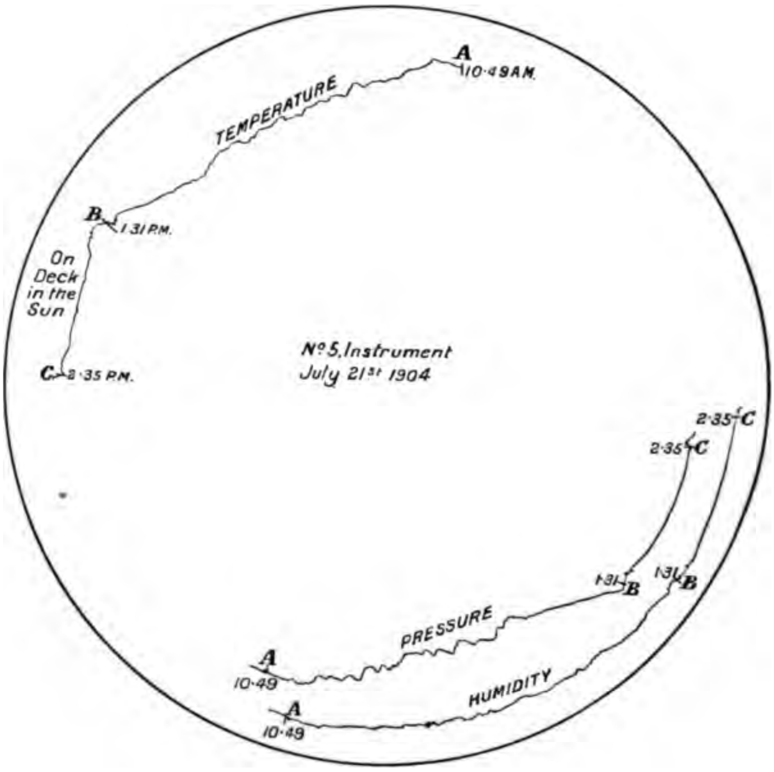


FIG. 1.

The barograph pen is actuated by an aneroid box made of thin metal, and sealed with some air at atmospheric pressure inside. The corrugated face of the box is very yielding, and hence the volume of the enclosed air is dependent chiefly on the external pressure and on its own temperature. The arrangement necessitates a large correction for temperature, but the result has proved satisfactory, since independent observations of the height of the kite have agreed with the heights given by the meteorograph within $2\frac{1}{2}$ per cent, instead of the 5 per cent

previously given by the exhausted boxes. The scale is approximately 1 inch to 5000 feet (1 mm. to 60 metres).

The hygrograph depends on the extension of a bundle of human hairs 6 ins. (15 cm.) long multiplied eightfold by a lever. Although the scale is short it is probable that this arrangement enables the relative humidity to be determined to within about 5 or 10 per cent. All the remarks made in the previous paper about the hygrograph apply here also, excepting that the hairs are protected from rain and spray.

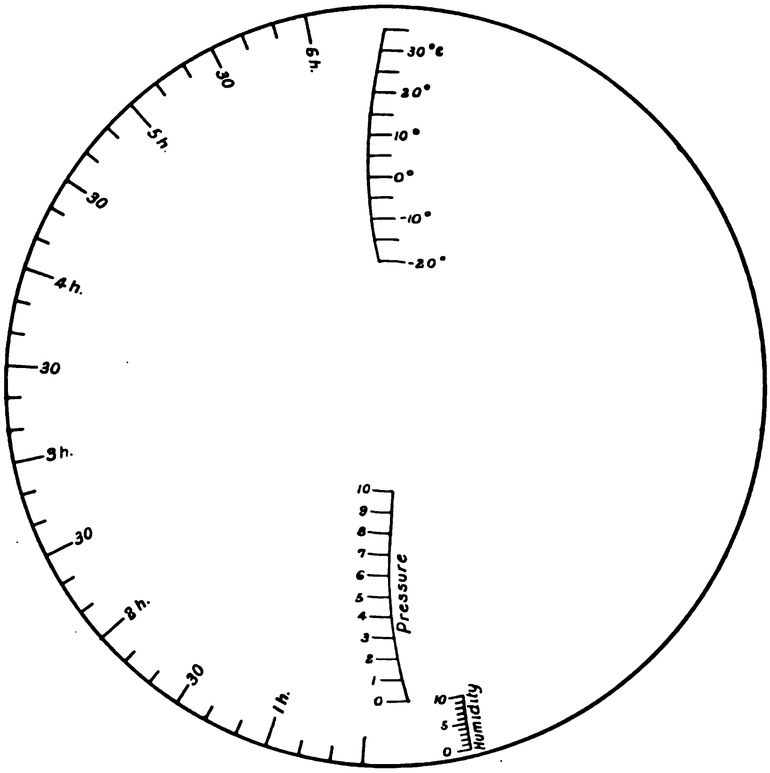


FIG. 2.

The thermograph depends on the expansion of ether or spirit enclosed in a thin brass tube, $\frac{1}{4}$ in. diameter and 20 ins. long (6 mm. diameter, 50 cm. long); this communicates with a small aneroid box also full of ether, the expansion and contraction of which actuates the pen. The scale was obtained by direct comparison with a mercurial thermometer between the temperatures 20°-80°, and at Crinan readings of a thermometer placed in a Stevenson screen on board the ship were always taken before each ascent as a check. The scale is about 30° F. to one inch (1° C. to 1·5 mm.). The arrangement gives a powerful control over the pen, so that blurring due to the shaking of the meteorograph seldom occurs, and the temperature is easily read to 0°·5.

The pens write on plain discs of paper, and the traces are tabulated

by placing the paper discs under a transparent celluloid disc on which the scales are engraved (Fig. 2). The certainty of synchronous readings is ensured in the following manner:—On each trace, while the paper is on the meteorograph, nicks A B C are made simultaneously by hand by the pens (Fig. 1). On placing the celluloid transparency on the paper, with a pin through the centres of both, by turning it round it should be possible to make each nick on the trace come exactly under the corresponding arc engraved on the celluloid. If this can be done, the points on the traces of the barograph, hygrograph, and thermograph which lie under the corresponding arcs on the celluloid must be simultaneous points on the traces, and if not, allowance can be made.

Any time scale that is convenient may be given to the meteorograph. At Crinan the disc was made to turn once in twelve hours, which gave an available period of six hours for each ascent without overlapping of the pens. As previously stated, the time scale is variable, but for the usual position of the pens this gives about 2 inches for each hour.

FIG. 3.—Meteorograph.

A time scale is engraved on the circumference of the transparency, and by fixing the paper disc with the trace on it underneath, and turning the transparency so that a certain mark corresponds with a definite instant on the time scale, the meteorograph readings at that instant can be read off. Of course the clock of the meteorograph must have been regulated to agree with the engraved time scale.

The general plan of this meteorograph is shown in Fig. 3, which has been obtained from a photograph. The thermometer bulb and the hygrometer hairs are underneath, where they are protected from solar radiation and rain, but fully exposed to the wind as it blows through the kite. A cover of thin varnished cloth (not shown) is provided to protect the paper disc from wind and rain. The total weight is 1¾ lbs. (·8 kilogram).

Lag of the Thermograph.

The difficulty of obtaining accurate temperature observations lies rather in applying a correction for the lag of the thermometer than in the tabulation of the records. The perpetual change of temperature that so commonly occurs at the earth's surface is more or less masked by the sluggishness of the ordinary mercurial thermometer, but the trace from a sensitive thermograph, such as Prof. Callendar's, shows how large and rapid the fluctuations may be. Rapid variations occur in the free air, and it is a matter of some interest to ascertain how they are associated with the circulation of the atmosphere. For this purpose, it is essential to be able to ascertain the true temperature from the trace at a point where it is rapidly changing, and to do this the allowance that should

be made for the lag must be determined. Unfortunately this is not uniform, but depends on the intensity of the ventilation, which again depends on the strength of the wind. An attempt has been made to determine the usual amount of lag for this special type of meteorograph. The instrument was suspended in the position it always occupied in the kite, with regard to the vertical and the wind direction, in a fresh breeze. The strength of the wind was estimated as equal to that to which the kites were most usually exposed, and by choosing cloudy days with a wind off the sea fair uniformity of temperature was obtained. The temperature of the thermograph was artificially raised, and the pen then allowed to settle to its proper position. A series of curves so

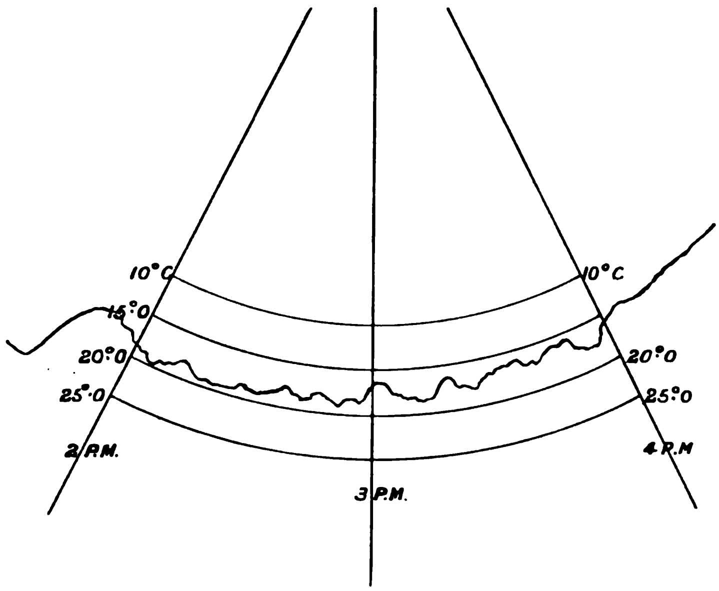


Fig. 4.

obtained suggested the following rule: To obtain the temperature at the time t, draw a tangent to the trace where it crosses the ordinate $x = t$; the true temperature will be obtained by noting where this tangent crosses the ordinate $x = t + 1$ minute.

The sensitiveness of the thermograph may be estimated by reference to Fig. 4. The temperature trace there shown was obtained by suspending the meteorograph in its usual position from the boughs of a tree on a sunny day with a pleasant breeze. Fig. 5 is a diagram kindly made for me by Mr. J. H. Field of the Indian Meteorological Service, and it is reproduced to show the extent to which the rule given above may be relied on. The diagram represents the trace obtained on July 13. On that date the kite, for some unknown reason, made a series of extensive dives, and thus the meteorograph was carried rapidly and several times successively through a large range of temperature and altitude. Apart from the improbable hypothesis that the

temperature at a definite height varied in unison with the diving of the kite, the diagram affords evidence that the rule enables a close approximation to be made to the true temperature even at a time when it is changing rapidly.

It might perhaps be questioned whether it would not be better to exhaust the aneroid box in the ordinary way, so as to avoid the necessity of a correction for temperature. The plan of leaving air in the box was adopted on the advice of Dr. Shaw, F.R.S., and, as has been already stated, has given good results. The temperature correction is a simple one

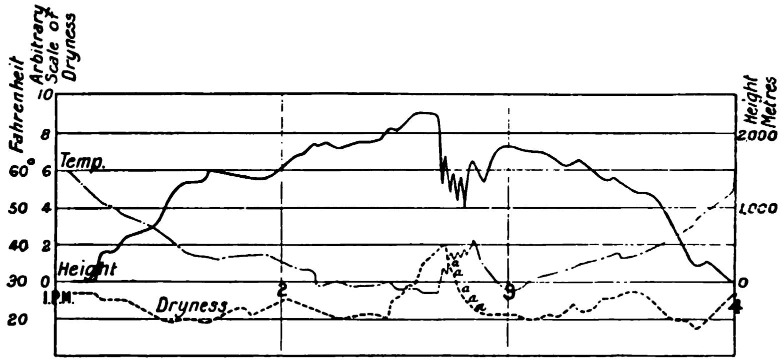


FIG. 5.

so long as the heights do not exceed 12,000 ft. (see note A, p. 223), namely, a simple addition of so many feet to the height for each degree that the temperature has fallen. It is doubtful if this rule will hold for very low pressures such as may be obtained by sending up a meteorograph with an unmanned balloon, but there is no difficulty about the experimental determination of the correction. This may be a good place to point out that the meteorographs are not suitable for balloon work as they stand, but they can easily be made so by ventilation of the thermograph. The temperature correction has an incidental advantage.

The temperature of the air is the most important matter, and if, as sometimes unfortunately happens, the thermograph trace should be defective, it is still possible, provided the height at the time was known by independent observation, to ascertain the approximate temperature from the discrepancy between the observed height and that shown on the barograph.

It cannot be said that the hygrometer scale is altogether satisfactory, since the zero point is liable to alteration, neither has the scale as yet been accurately determined, but with care I do not think the errors should exceed 5 per cent.

A very fair number of observations on the temperature gradient have now been obtained, and I hope to deal with the whole set on some future occasion; it will suffice here to give the gradients on each day of last summer on which observations were made.

The weather conditions at Crinan were somewhat unusual, there being a decided preponderance of East and South-east winds. The air on the summit of Ben Nevis was often dry, and was on several occasions warmer

than the air at the same level near Crinan. With one exception, these instances were associated with an East or South-east wind, and were accompanied with extreme dryness on the summit of the mountain. In the previous years no example of a higher temperature on the mountain occurred, and this year the temperature at the kite was, except once, above the wet-bulb temperature on Ben Nevis. The rule still holds that the temperature on the Ben is as a rule much lower than the temperature in the free air at the same level.

Several times temperature inversions were observed at levels between 3000 and 7000 ft.; this also was contrary to the experience of the preceding years.

A fact previously noticed was again observed, namely, the decrease of strength of Easterly winds with elevation. Mr. Rotch called attention to this some time since at Blue Hill. It is certainly the case at Oxshott, and was particularly noticeable during the last fortnight's observations at Crinan. The wind was persistently East and South-east, and day after day it was found that a kite could not be raised above a certain level owing to want of wind in the higher strata. At Oxshott, at 2000 ft. elevation, a Westerly wind has generally double the velocity that it has at the anemometer head, excepting on days when the solar insolation is strong; on the other hand, an Easterly wind has generally decreased before 2000 ft. are reached. At Oxshott there is a very good exposure to the East and a bad one to the West, so that the result might well be put down to local conditions.

It can be shown that the tendency of the earth's rotation, except near the poles, is to cause an air particle moving from the West to rise, and one moving from the East to sink. The numerical effect is extremely small, but it may suffice to explain the phenomenon. In latitude 45° the tendency of an easterly moving particle to rise is exactly equal to its tendency to turn to the right hand; and similarly for a westerly moving particle the tendency is to fall. With a North or South wind no appreciable effect is produced. It follows that with an Easterly wind those particles that are moving faster than the average may be looked upon as having a rather greater weight than the average; these particles therefore sink, and the greatest velocity is found near the surface. Conversely with a West wind, but here the greatest velocity should be at the top. It might be thought that the numerical value of this tendency would be too small to produce any effect. With a velocity of 50 miles per hour in latitude 45° the tendency to rise or fall is the same as would be produced by a change of about ·02 per cent in the density. At this latitude (45°) it is equal to the tendency that a moving body has to turn to the right, and there can be no doubt about the important effect which this has in meteorological matters.

NOTE A.

To determine the correction for change of temperature to be applied to the height given by the barograph chart.

Let V be the volume of air inside the aneroid box, P the internal pressure, and T the absolute temperature assumed to be the same inside and out.

The $$\frac{VP}{T} = \text{constant},$$

hence $$dV = V\left(\frac{dT}{T} - \frac{dP}{P}\right).$$

The position of the barograph pen is dependent only on V, so that the position of the pen is unaltered by a change of temperature dT, if $dV = 0$, that is, if the meteorograph is raised or lowered to such an extent that the pressure P is altered by dP, where

$$dP = \frac{P}{T}dT \quad . \quad . \quad . \quad . \quad . \quad \text{I.}$$

Let h be the altitude, p the external atmospheric pressure, then

$$g\rho dh = dp \quad . \quad . \quad . \quad . \quad . \quad \text{II.}$$

Suppose $$p = P + p_0,$$

then $$dp = \left(1 + \frac{dp_0}{dP}\right)dP \quad . \quad . \quad . \quad \text{III.}$$

Also ρ, the density of the air, varies as $\frac{p}{T}$.

Hence, eliminating,

$$dh = A\frac{T}{P + p_0}\left(1 + \frac{dp_0}{dP}\right)dP, \text{ where A is a constant},$$

$$= A\frac{T}{P}\left(1 + \frac{p_0}{P}\right)^{-1}\left(1 + \frac{dp_0}{dP}\right)dP,$$

$$= A\left(1 - \frac{p_0}{P} + \ldots\right)\left(1 + \frac{dp_0}{dP}\right)dT,$$

$$= A\left(1 - \frac{p_0}{P} + \frac{dp_0}{dP} + \ldots\right)dT.$$

If the terms $\frac{p_0}{P}$ and $\frac{dp_0}{dP}$ may be neglected, we have in so far as the correction is concerned $h = At$ + constant, and the correction is obtained by adding so many feet or metres to the height given by the barograph for each degree Fahrenheit or centigrade that the temperature has fallen.

The instrument is so constructed that p_0 is initially a positive quantity. As the meteorograph rises, the aneroid box expands and p_0 decreases. P and p_0 decrease together so that $\frac{dp_0}{dP}$ is always positive. The terms, therefore, to some extent cancel each other. Using thin metal for the box, so that p_0 must always be small, the combined terms may be neglected, or at least $A\left(1 - \frac{p_0}{P} + \frac{dp_0}{dP}\right)$ may be taken as constant, for heights at which P is not too much reduced, and heights great enough to unduly reduce P can hardly be reached by a kite.

Were the meteorograph sent up with an unmanned balloon, p_0 might well become negative and nearly as large as P. In this case the temperature correction would have to be determined experimentally, but for work with free balloons it would be better to use an exhausted box.

TABLE A.—TEMPERATURE GRADIENTS AT CRINAN, 1904.

Heights	0 ft. to 1660 ft.	1660 ft. to 3330 ft.	3330 ft. to 5000 ft.	5000 ft. to 6660 ft.	6660 ft. to 8330 ft.
	°	°	°	°	°
June 20	5·0	4·8			
,, 21	10·8	2·3	5·8		
,, 22	6·7	5·0	7·0		
,, 24	10·6	3·6			
,, 25	9·0	6·0			
,, 27	10·8				
,, 28	10·0	3·2	6·2	5·6	6·2
,, 29	3·6	6·5	6·5		
,, 30	4·8	7·7	6·3		
July 1	8·2	6·9	3·6		
,, 2	11·0	7·2	1·8		
,, 4	9·0	4·7	3·2	3·8	
,, 5	9·0	6·3	−8·2	4·9	
,, 6	4·5	3·8	3·8		
,, 7	9·9	8·1	3·6	5·4	
,, 8	4·5	4·6	4·8		
,, 13	9·7	5·4	5·6	6·8	5·4
,, 14	3·1				
,, 15	8·6	1·8	2·8	6·1	2·3
,, 16	5·4	6·3	2·7	−3·2	
,, 18	2·2				
,, 19	4·5	4·5			
,, 20	5·2	5·2			
,, 21	6·8	5·7	4·3		
,, 22	3·2	5·2	4·9	4·5	
,, 25	6·5	2·3	5·1		
,, 26	9·9	4·2	−5·1		
,, 28	3·8	4·1	−1·3	6·0	5·1
Means	7·0	4·8	3·1	4·5	4·7
Degrees per 1000 ft.	4·3	3·0	1·7	2·5	2·6

TABLE B.—TEMPERATURE DECREASE IN DEGREES FAHRENHEIT PER 1000 FEET.

Height of Columns	0 ft. to 1660 ft.	1660 ft. to 3330 ft.	3330 ft. to 5000 ft.	5000 ft. to 6660 ft.	6660 ft. to 8330 ft.	8330 ft. to 10,000 ft.
	°	°	°	°	°	°
Balloon ascents at Berlin	...	2·7	...	2·7	...	...
Kite ascents in United States	6·0	4·4	3·9	3·7	...	...
Average gradient for mountains			1° for every 300 feet.			
Adiabatic gradient for saturated air, initial temperature, 54°·0	2·75	3·0	...	2·9	...	3·4
Average for the sea off the W. coast of Scotland, lat. 54°, July and August 1902	3·1	3·1	2·8	2·7	2·6	2·5
August 1903	2·4	3·7	4·0	...	...	...
June and July 1904	4·3	3·0	1·9	3·7	3·9	...

The upper part of this table has been taken from one previously given by Dr. Shaw and the author.

DISCUSSION.

The PRESIDENT (Mr. R. BENTLEY) remarked that it was not necessary to-night to lay so much stress on the value of Mr. Dines's services in carrying out the investigations at Crinan, which had been so recently before the Fellows of the Society and were in the memory of all, as on the importance of the new instrument that he had brought out. The great advantage it possessed over those previously used was its strength, lightness, and cheapness. With regard to using human hair for obtaining the changes in hygrometric conditions, such a plan had been in use for over a century, and it would be interesting to discover if any difference in the results was noticeable by using the hair of an older or younger person, according to its elasticity.

Mr. R. INWARDS said they would all be glad to welcome the new form of Meteorograph. Besides being much lighter and cheaper than the old pattern it seemed to be quite as effective. He thought it ought to be possible to automatically correct the barometer readings for temperature error.

Dr. W. N. SHAW called attention to some advantages of the apparatus which had not been specially mentioned by Mr. Dines.

Mr. J. E. CLARK said he was struck with the wonderful simplicity of the instrument and that accuracy had not been sacrificed for cheapness. He thought, however, that a simple coil of tube opening out and closing with the changes of temperature might prove more effective than the aneroid box.

Mr. R. H. CURTIS said that he had a vivid recollection in the previous experiments of the great difficulty of getting satisfactory measurements of the meteorograph traces, owing to the vibration and jerking of the kites, which often had the effect of altering the shape of the curves. In the present method the result was much better, and it was now possible to obtain measurements with a greater degree of accuracy. This alone was of the greatest advantage.

Mr. F. GASTER remarked that the new meteorograph bore that feature of accuracy and wonderful simplicity that it was customary to find in all Mr. Dines's work. Instances would be called to mind in his sunshine recorder and anemometer where it was possible to sit comfortably indoors and watch the instruments in full working order. High-level observations were of immense value; but he thought that if the observations were taken from the top of a high mountain conjointly with observations below, better results would be obtained. He believed the influence of a mountain like Ben Nevis on the surrounding country would be very great both as regards pressure, temperature, and other meteorological elements.

Mr. W. MARRIOTT said that when addressing the visitors at the recent Exhibition he had had to apologise for the frequent use of Mr. Dines's name, for it almost seemed as though no one else had done anything in the way of new instruments. The Fellows were greatly indebted to Mr. Dines not only for the meteorograph, but also for the work entailed in carrying out the observations at Crinan. Mr. Dines himself said very little about the labour involved, but the table at the end of the paper was the result of a lot of hard work. One very interesting point brought out in the paper was the decrease in force of the East wind with elevation. Information on such facts as this would throw valuable light on other points.

Mr. W. H. DINES said in reply that probably the necessary information as to the contraction and expansion of human hair under varying hygrometric conditions was available, but he did not know precisely where to look for it. It was admitted by all that the zero point of the hair hygrometer was not constant.

The new instrument was placed in the kite instead of being hung upon the

wire. Whether this would make the trace steadier or the reverse he could not say, but it saved time and trouble ; and if on land the kite broke away, the instruments were undamaged by the fall. Over the sea, unless it were quite calm, there was practically no chance of recovering a kite that had broken away, since the small patch of white that it showed when floating was exactly like the white patches caused by the breaking waves. He hoped some of the Fellows of the Society might be induced to take up kite-flying. To reach a height of 4000 or 5000 feet on suitable days did not require very costly apparatus or involve much trouble ; neither was there much risk of damaging the meteorograph, for the one he (Mr. Dines) was now using had made fifty ascents and was still in use. If three observers could be found to make ascents some 60 miles apart on selected days, much interesting information could be obtained. He might refer to temperature inversions, for example. Were these local phenomena, or did they extend over large areas? There were many questions of this kind awaiting solution.

Optical Convention, 1905.

This Convention was held at the Northampton Institute, Clerkenwell, from May 31 to June 3, under the presidency of Dr. R. T. Glazebrook, F.R.S., Director of the National Physical Laboratory. The papers and discussions were on optical subjects ; but in connection with the Convention there was a large and interesting Exhibition of optical and scientific instruments. One of the classes was specially set apart for "Meteorological Instruments and Temperature Measures." The instruments were exclusively the work of English makers. The meteorological instruments included Barometers, Self-Recording Barometers, Thermometers, Self-Recording Thermometers, Hygrometers, Anemometers, Sunshine-Recorders, Rain-Gauges, Evaporimeters, etc.

Radcliffe Observatory, Oxford.

The usual meteorological observations and automatic registers have been maintained during the year 1904 and the results sent regularly as heretofore to the Meteorological Office (by daily telegram), the Registrar-General, the Thames Conservancy, local newspapers, and to public and sanitary authorities upon request, and to numerous private inquirers.

The five underground platinum thermometers were in daily use and have been free from derangement throughout the year. The zero of leads has occasionally shifted through small ranges in the thousandths of a degree centigrade. These ranges, although practically negligible, have been corrected for in the results, and appear to arise from the effects of cleaning the surfaces of the contact pieces and from slight torsional strain in the flexible leads from the switch-board to the resistance box. All the automatic instruments performed well and were subjected to the usual process of cleaning and inspection during the autumn.

The following are the chief characteristics of the weather noted at Oxford during the year 1904 :—

The mean reading of the barometer (reduced to 32°) was 29·745 ins., which is ·020 in. higher than the mean for the preceding 49 years. The highest reading was taken on January 22, 30·507 ins., the lowest 28·403 ins. on February 9 ; showing a range in the year of 2·104 ins.

The mean temperature of the air was 48°·8, only 0°·1 below the mean for the preceding 76 years. The maximum temperature 84°·5 occurred on July 17, the minimum 16°·9 on November 24, and the lowest on the grass 13°·4 on November 26. This minimum 16°·9 of the air is the lowest recorded

at this Observatory in the month of November since the year 1858 (November 23) when the reading was 15°·7.

The differences of the mean monthly temperatures from the corresponding means for the preceding 76 years are—

January	+1·3	May	-0·1	September	-1·5
February	-0·8	June	-1·5	October	+0·1
March	-1·3	July	+2·7	November	-2·1
April	+2·2	August	+0·2	December	-0·3

Bright sunshine was recorded during 1477 hours, or 21 hours above the mean for the preceding 24 years. The monthly differences from the mean are—

	Hours.		Hours.		Hours.
January	-10	May	-55	September	+27
February	-11	June	+ 8	October	-12
March	-23	July	+42	November	+ 9
April	+13	August	+40	December	- 7

Rainfall on the ground amounted to 23·555 ins., a total 2·573 ins. less than the mean for the preceding 89 years.

	in.		in.		in.
January	+1·342	May	+1·322	September	-1·334
February	+1·441	June	-1·188	October	-1·975
March	-0·410	July	+0·908	November	-0·760
April	-0·903	August	-0·884	December	-0·132

The low-lying lands in the neighbourhood of the city were flooded during part of the month of February.—ARTHUR A. RAMBAUT, *Radcliffe Observer.*

Form and Structure of Lightning Flashes.

Monsieur W. Prinz, of the Royal Observatory, Brussels, has prepared a careful digest of the available information on the subject of the form and structure of lightning flashes as shown in the various photographs which have come under his investigation. This is printed in the *Annales Météorologiques* de l'Observatoire Royal de Belgique, vol. 14.

He adopts practically the nomenclature of Abercromby and the Royal Meteorological Society, and gives many illustrations of the diverse forms of lightning. On the subject of the duration of the flashes, after quoting various authorities, the author concludes that it may be taken as practically instantaneous —and he gives a table of duration according to the experiments of Weber, Pickering, Glew, and Walter. As to the length of the flash, he quotes an instance of one extending to seven and a half miles.

He proceeds to analyse the various complicated knots of some of the photographs, and reduces them to effects of perspective and foreshortening, while the same explanation is given of the apparent star-like, radiant, and globe-like forms. He remarks that oscillatory discharges have never come under his observation, and that all lightning strokes pointing to the earth are, as they seem, downward discharges.

He suggests further observations with telephoto lenses of large aperture, and gives a bibliography of the whole subject at the end of his interesting paper.

RATE OF FALL OF RAIN AT SEATHWAITE.

By HUGH ROBERT MILL, D.Sc., LL.D., F.R.Met.Soc.

[Read April 19, 1905.]

THE rate at which rain falls can only be accurately determined by the use of a self-recording rain-gauge, and to speak with any degree of confidence regarding the average rate of rainfall one must have the records of such a gauge for several years.

Peculiar interest attaches to Seathwaite from the point of view of rainfall observations, because it is one of the wettest spots in England, and because rainfall has been measured there for an exceptionally long period. In 1899 the late Mr. Symons set up a Negretti and Zambra recording rain-gauge at Seathwaite, where it remained in operation from July 10, 1899, to December 31, 1900, when the record unfortunately ceased. Although eighteen months is far too short a time on which to found any definite opinion as to the rate of fall of rain, there is reason to believe that at Seathwaite even so short a record may yield results of interest.

The gauge in question, which has the merit of being inexpensive, gives a step-by-step trace, each step recording the fall of ·01 in. of rain, and the drum carries a diagram ruled for seven days, a period during which the clock may gain or lose considerably. In a heavy shower the resulting curve is practically a continuous line, and changes of rate are readily observed and measured; but though quite satisfactory during heavy rain, the steps in a gentle drizzling rain are so long that it is impossible to utilise the record to measure time or rate of fall. Quantities of ·01 in. or ·02 in. falling in twenty-four hours must, consequently, be left out of account.

For the purpose of comparison, the fall at Camden Square, London, was discussed in a manner similar to that at Seathwaite; but the record was from the very costly Casella gauge, which draws a continuous trace on a drum carrying a diagram for twenty-four hours. The London record being taken by what may be viewed as a standard gauge, is thus of a higher order of accuracy; but as the average number of rainy days at Seathwaite is 33 per cent greater than at London, and the total rainfall is five times greater, the disparity is not so serious as it would be for places of equal wetness.

If the rate of fall of rain is considered with regard to the rainfall day as a unit, the rate at Seathwaite averages ·61 in., or considerably over half an inch per rainy day, while that at Camden Square averages ·15 in. per rainy day, or almost exactly one-quarter of the rate. These figures are the average of 38 years 1865-1902. Such a comparison does not require the use of a recording gauge, and it leads to a perfectly just estimate of the relative average wetness of localities. It does not, however, answer many questions which arise as to distribution of rainfall throughout the day, or the variations in the rate of fall from hour to hour.

The Seathwaite record cannot be used for purposes of exact analysis,

because the time-scale is too contracted, and the rate of the clock too uncertain to allow of the tabulation of the amount of rain falling in each hour of the twenty-four. It was found practicable to discuss the curves so as to yield:

(1) Average rate at which the rain fell on each rainfall day, *i.e.* from 9 a.m. to 9 a.m.
(2) Average rate at which the rain fell on each civil day, *i.e.* from midnight to midnight.
(3) Average rate at which rain fell during daylight, *i.e.* from sunrise to sunset.
(4) Average rate at which rain fell during darkness, *i.e.* from sunset to sunrise
(5) Average rate at which rain fell in showers yielding ·5 in. or more.
(6) Average rate at which rain fell in showers of six hours' duration or longer.

It has been usual to speak of day and night rain when the periods taken are from 9 a.m. to 9 p.m., which are mainly daylight, and from 9 p.m. to 9 a.m., which are mainly darkness; but this corresponds to no physical difference between day and night. The hours of sunrise and sunset for Seathwaite were therefore calculated, and the curves measured for the actual periods between the times of sunset and sunrise. As it was impracticable to read the time-scale closer than to quarters of an hour, no allowance could be made for refraction, so that in adding up for a year the amount of daylight rain would tend to be slightly underestimated; but the difference is too minute to affect the results.

Table I. gives for each month the actual fall of rain, the number of hours during which rain fell, the number of days with rain, and the mean rate of rainfall in decimals of an inch per hour.

TABLE I.—SEATHWAITE RAINFALL (Rainfall Days).

Months.	1899. No. of Rainy Days.	Hours of Rain.	Inches of Rain.	Rate of Fall. Per Rainy Day.	Per Hour.	1900. No. of Rainy Days.	Hours of Rain.	Inches of Rain.	Rate of Fall. Per Rainy Day.	Per Hour.
				in.	in.				in.	in.
January	...	...	...	...	...	28	163½	16·35	·584	·100
February	...	...	...	...	...	23	127¾	9·91	·431	·078
March	...	...	...	...	...	12	17½	·98	·081	·056
April	...	...	...	...	...	18	77	8·12	·451	·105
May	...	...	...	...	...	13	65¾	7·26	·559	·110
June	...	...	...	...	...	19	83	7·93	·417	·096
July[1]	16	65	5·05	·316	·078	19	58¼	4·04	·213	·069
August	15	38¼	3·69	·246	·096	19	105¼	12·24	·664	·116
September	24	87½	12·34	·514	·141	16	87¼	9·98	·624	·114
October	13	81¼	12·75	·980	·157	24	134	13·87	·578	·104
November	25	129	14·62	·585	·113	21	99¾	9·71	·462	·097
December	17	100¾	8·24	·485	·082	28	174¾	25·83	·920	·148
Year[1]	110	501½	56·69	·515	·113	240	1193¾	126·22	·526	·106
Monthly Means	19	90¼	9·45	·515	·113	20	99½	10·52	·526	·106

[1] From July 9.

The correctness of the measurement of the daylight and darkness rainfall was checked by the independent measurement of the rainfall of the civil day; which also served to check the measurement of the fall of

the rainfall days, which in turn was checked by the reading of the ordinary gauges at Seathwaite. The rainfall and civil days giving practically identical rates, it is unnecessary to consider more than one of them. The separate treatment of continuous falls of rain lasting for six hours or more, and of continuous falls of rain aggregating half an inch or more, gives prominence to falls which were most remarkable both for duration and for amount. Such continuous falls may for brevity's sake be termed showers, and it is interesting to study them, because they are natural units, not mere arbitrary divisions of time or quantity.

As only the records of one year can be discussed completely, it is necessary to receive the results merely as indicative of the character of the Seathwaite rainfall, but comparisons can be made with the Camden Square record for the same year which gives some clue to the different rainfall régimes of the drier and wetter parts of England.

The irregularity of the figures makes it impossible to draw any conclusion as to the variation of the rate of fall of rain with the season. The whole period of nearly a year and a half may, however, be compared with the readings at Camden Square as follows:—

RATE OF FALL OF RAIN FROM JULY 10, 1899, TO DECEMBER 31, 1900.

	No. of Rainy Days.	Hours of Rain.	Inches of Rain.	Rate. Per Rainy Day.	Rate. Per Hour.	Hours per Rainy Day.
				in.	in.	
Seathwaite . . .	350	1695	182·91	·523	·108	4¾
Camden Square . .	196	484	32·15	·164	·066	2½
Ratio of Seathwaite if Camden Square = 100	179	350	569	319	164	190

This shows that the total duration of rain at Seathwaite was more than three times as long as in London, the amount falling nearly six times as great, and the rate of fall consequently nearly twice as rapid. Looking at the figures from another point of view, we find that on the average two days out of every three had rain at Seathwaite; and one out of every three had rain in London; or again, one hour out of every 8 was continuously wet at Seathwaite, and one out of every 27 continuously wet in London. The actual figures are:—

	Total Days.	Days with Rain.	Per cent.	Total Hours.	Hours of Rain.	Per cent.
Seathwaite	539	350	65	12,936	1695	13
Camden Square . .	539	196	36	12,936	484	3·7

As a corrective we may recall the fact that on the average of a long period the number of rainy days in a year at Seathwaite is 216 or 59 per cent of the year, or 3 in every 5; while in London the number of rainy days is 163, or 45 per cent of the year, or nearly 1 in every 2. Also when the number of very long showers at Seathwaite is taken into account, it is found that there are really frequent intervals of fine dry weather.

As the recording gauge came into use within three weeks of the summer solstice, no serious error is introduced by taking the whole period of nearly eighteen months into consideration, and the last line of Table II. seems to show a tendency towards greater amount, duration, and intensity of rainfall during the hours of darkness as compared with the hours of daylight. The difference is small, and does not always appear. For the whole year 1900, for example, out of 1191½ hours of duration of rainfall

595 were in daylight and 596½ in darkness, a difference which certainly lies within the limit of probable error in measuring the curves. Several years' observations would be necessary before the relationship could be accepted as proved; but it is certainly indicated that about 5 per cent

TABLE II.—SEATHWAITE RAINFALL.

	Daylight.				Darkness.			
	No. of Days with Daylight Rain.	Fall.	Duration.	Rate per Hour.	No. of Days with Darkness Rain.	Fall.	Duration.	Rate per Hour.
1899.		in.	hrs.	in.		in.	hrs.	in.
July[1] . .	13	2·91	39¼	·074	7	2·14	25	·086
August . .	13	1·97	25¼	·078	6	1·66	13¼	·125
September .	21	6·54	54¼	·121	11	6·33	37¼	·170
October . .	10	6·29	37	·171	12	6·44	44	·146
November .	15	4·94	44¼	·112	21	9·70	84¾	·114
December .	14	1·83	24	·076	15	6·39	76¼	·084
Year[1]. .	86	24·48	224¼	·109	72	32·66	280½	·116
1900.								
January . .	23	7·71	73½	·105	26	8·59	89¾	·096
February .	22	4·62	79	·058	12	5·28	48¾	·108
March . .	10	·74	12	·062	4	·24	5½	·044
April . .	16	5·73	45¾	·125	11	2·40	31	·077
May . .	13	4·51	44¼	·102	7	2·74	21¾	·126
June . .	17	5·60	51½	·109	12	2·15	27	·080
July . .	15	2·85	46¼	·062	10	1·32	16¼	·081
August . .	18	9·87	72¾	·136	11	2·35	32½	·073
September .	14	3·56	35	·102	11	6·40	52	·123
October . .	19	7·04	59¾	·118	21	6·60	73	·090
November .	13	3·31	32	·103	19	6·53	68½	·095
December .	17	5·74	43¼	·133	28	20·06	130½	·154
Year . .	197	61·28	595	·103	172	64·66	596½	·108
Whole Period .	283	85·76	819¼	·105	244	97·32	877	·111

[1] From July 10.

more rain falls during darkness than during daylight at Seathwaite. At London it would appear that the relation is reversed; but we hope on an early occasion to go somewhat fully into the many years' records which have been accumulated at Camden Square, and for the present it is enough to express the figures for 1900 in a form permitting of easy comparison. This is done by taking the daylight rainfall as 100, when the following ratios come out:—

	Daylight.			Darkness.		
Place.	Duration.	Amount.	Rate.	Duration.	Amount.	Rate.
Seathwaite . .	100	100	100	100	106	105
Camden Square .	100	100	100	110	92	85

The difference between the amount, duration, and rate of rainfall at Seathwaite during daylight and darkness being so small, it was felt to be sufficient to treat the individual showers without reference to the hour at which they occurred. That individual showers must be considered in different ways is evident when one reflects how greatly the intensity of rainfall varies with duration. Thus a single sharp thunderstorm may bring down three inches of rain in an hour, while a steady soaking rain may mean a fall of less than half an inch for a day without a dry hour. Accordingly we have studied the Seathwaite showers irrespective of

rainy days whenever the amount exceeded half an inch, or the duration exceeded six hours. In this way no fall of rain remarkable either for intensity or duration could escape notice. The results are summarised in Tables III. and IV.

TABLE III.—SEATHWAITE. CONTINUOUS RAINS EXCEEDING HALF AN INCH.

Amount.	No. of Cases.	Duration. Mean.	Duration. Max.	Duration. Min.	Rate per Hour. Mean.	Rate per Hour. Max.	Rate per Hour. Min.
in. in.		h. m.	h. m.	h. m.	in.	in.	in.
·50– ·99	45	6	11 30	1 15	·14	·40	·05
1·00–1·49	19	7 30	14 30	2 30	·20	·56	·10
1·50–1·99	11	9 30	18	4	·22	·41	·10
2·00–2·49	6	11 30	18	7	·22	·34	·12
2·50–2·99	3	15	18 45	11 30	·20	·26	·16
Above 3·00	4	20	30	14 30	·20	·23	·13
Above ·50	88	8	30	1 15	·17	·56	·05

Table III. contains a classification of all heavy showers according to the total amount which fell in each. It is seen that there were altogether 88 showers with more than half an inch of rain in the 539 days under consideration, an average of rather more than one per week. Of these 45 produced less than an inch of rain, and only 13 more than 2 inches. The mean duration of such a shower was 8 hours, the greatest 30 hours, and the least $1\frac{1}{4}$ hours. The showers yielding less than 1 inch had a mean duration of 6 hours and a mean rate of fall of ·14 ins. per hour, though with a great range. The showers yielding larger amounts were proportionally shorter, for it is seen that although the mean duration was $7\frac{1}{2}$ to 20 hours, the mean rate was either ·20 ins. or ·22 ins. per hour, showing that at Seathwaite the long-continued rains are on the whole the heavier.

TABLE IV.—SEATHWAITE. CONTINUOUS RAINS EXCEEDING SIX HOURS.

Duration.	No. of Cases.	Amount. Mean.	Amount. Max.	Amount. Min.	Rate per Hour. Mean.	Rate per Hour. Max.	Rate per Hour. Min.
h. h. m.		in.	in.	in.	in.	in.	in.
6– 7 45	40	·86	2·40	·24	·13	·34	·03
8– 9 45	23	1·02	2·41	·29	·12	·25	·03
10–11 45	11	·84	2·92	·32	·08	·27	·02
12–13 45	2	1·96	2·19	1·73	·15	·17	·13
14–15 45	4	1·36	3·30	1·43	·16	·23	·10
16–17 45	3	2·72	3·77	2·08	·16	·23	·13
18 and over	4	3·11	4·03	1·89	·15	·19	·11
Over 6 h.	87	1·16	4·03	·24	·12	·34	·02

Table IV. presents similar information as to showers exceeding 6 hours in duration, and of these there were 87. Forty of them had a duration between 6 and 8 hours, and 24 had a duration exceeding 10 hours. The longer continuous heavy falls showed a higher rate of rainfall than the shorter, although the smallest rate was yielded by the showers of from 10 to 12 hours' duration. The larger amount which fell in one continuous shower during the time of observation was 4·03 ins., and this also gave the greatest duration, for while it was falling the rain did not cease for 30 hours.

In the case of showers exceeding 6 hours in duration the following comparison shows the contrast between Seathwaite and London :—

	All Rains.			Showers over 6 Hours.				Ratio of Showers over 6 Hours to Total Rain = 100.		
	Duration.	Amount.	Rate per Hour.	No.	Duration.	Amount.	Rate per Hour.	Duration.	Amount.	Rate.
	hrs.	in.	in.		hrs.	in.	in.			
Seathwaite .	1695	182·91	·108	87	798	100·91	·126	47	55	117
Camden Sq. .	484	32·15	·066	20	183	10·57	·058	38	33	88

How far the period under consideration was exceptional may be judged from the fact that, during the two years 1899-1900, the rainfall at Seathwaite was within 1 per cent of the average, while that at London was about 10 per cent below the average. Hence the contrast is probably exaggerated in the Tables.

As a final result we can say, that the rainfall at Seathwaite in an average year shows a tendency to be slightly greater during the hours of darkness than in daylight, that rather less than half the time during which rain is falling it continues without intermission for at least six hours at a time, and that rather more than half the total amount of rain is deposited in such long showers.

The comparison with London is not insisted on because neither 1899 nor 1900 was an average year there, and because we have in view a more complete discussion of the whole matter.

DISCUSSION.

The PRESIDENT (Mr. R. BENTLEY) said that any consideration of the speed of rainfall was of great value to engineers, architects, and builders. The contrast between London and Seathwaite was very interesting, and the hope expressed in the paper of presenting in the near future another paper dealing with the rate of rainfall in London was something to look forward to. Seathwaite was in an exceptional position, like Ben Nevis, which made any information on its rainfall extremely valuable, but at the same time the paper on the London district—one containing several million inhabitants—could not fail to be one of the highest interest and utility.

Mr. J. HOPKINSON said that he knew Seathwaite and its neighbourhood well. He had known it to rain at Keswick nearly every day for a month, Derwentwater rising two feet during his stay there ; but he had also had nearly a month at Grasmere with only one really wet day. Having regard to the great variability of rainfall, he scarcely thought it to be "certainly indicated" by the author's figures that more rain falls at Seathwaite during darkness than during daylight.

Mr. W. MARRIOTT said, that at the request of Mr. Symons, the Royal Meteorological Society at the end of 1880 equipped a climatological station at Seathwaite, as it was considered that the observations from such a wet spot would be very interesting and valuable. Previous to inspecting that station in 1899, Mr. Symons asked him to see to the setting up of the Negretti and Zambra self-recording rain-gauge, the results from which were given in Dr. Mill's paper. He (Mr. Marriott) had some years ago read a paper before the Society on the rainfall at Seathwaite, in which he gave the results for the period 1881-97 (*Quarterly Journal*, vol. **24**, p. 42). The daily amounts were distributed as in the accompanying table :—

DISTRIBUTION OF RAINFALL AT SEATHWAITE, 1881-97.

Months.	No. of Days with falls between													Total Rainy Days.	Mean Rain-fall.
	·01	·02-·09	·10-·49	·50-·99	1·00-1·49	1·50-1·99	2·00-2·99	3·00-3·99	4·00-4·99	5·00-5·99	6·00-6·99	7·00-7·99	8·00-8·99		ins.
January .	6	62	126	62	38	21	12	3	2	...	...	...	...	332	12·25
February .	7	50	103	59	27	17	10	5	4	...	...	...	...	282	11·20
March .	7	69	118	58	33	23	5	3	3	...	...	...	...	319	11·38
April . .	13	68	92	46	18	5	6	...	...	...	...	...	...	248	6·04
May . .	8	74	106	35	25	7	4	2	1	...	1	...	...	263	7·32
June . .	10	48	112	49	17	6	2	1	2	...	...	...	...	247	6·52
July . .	8	99	112	62	31	10	10	4	...	...	...	...	...	336	9·98
August .	13	86	132	59	37	15	9	3	2	...	1	...	...	357	11·63
September	9	63	99	58	35	16	17	4	1	2	1	...	...	305	12·58
October .	12	67	111	63	41	19	12	2	2	...	...	...	...	329	12·04
November	3	57	106	72	56	18	16	3	...	...	...	...	1	332	14·07
December	11	71	101	79	49	16	20	6	2	...	...	...	...	355	15·05
Totals .	107	814	1318	702	407	173	123	36	19	2	3	0	1	3705	130·06

Forty per cent of the falls were over half an inch, which agreed with Dr. Mill's conclusions. The greatest fall in one day was 8·03 ins. on November 12, 1897. The spring months are the driest, as they not only have the least rainfall, but also the least number of rainy days. The most remarkable feature brought out in the table is the great increase in the number of rainy days from June to July. August has the greatest number of rainy days. From a comparison which he had made of the anemometer records at Fleetwood, with the rainfalls at Seathwaite exceeding 3 inches, he found that these heavy falls occurred when the general direction of the wind was South to South-west, and the velocity high. Grouped according to the rainfalls, the following results were obtained:—

SEATHWAITE. Rainfall.	No. of Instances.	FLEETWOOD. Wind Velocity.
3 inches.	21	561 miles.
4 ,,	12	636 ,,
5 ,,	2	662 ,,
6 ,,	2	724 ,,
8 ,,	1	539 ,,

It is thus seen that the stronger the wind the heavier is the rainfall. From an examination of the topography of the district, it will be readily apparent that when the wind is between the South-east and West, it will be concentrated in the valleys, and must rush up them with considerable force. In addition to this, the air current will have swept over the Irish Sea and Morecambe Bay without any obstruction until it reaches Furness and these hilly districts. Consequently, the air current will not only have to get over the passes, but will be forced up to a greater height. It is this forcing up of the air current, and consequent reduction of temperature, which is the cause of the heavy rainfall on the lee-side of the Scafell range.

He would have liked the records dealt with by Dr. Mill to be discussed in relation to the direction of the wind, as no doubt most interesting results would have been obtained.

Mr. R. H. HOOKER, referring to the remark that more rain fell during darkness than during daylight, thought that the difference shown at Seathwaite was not sufficient, in view of the relatively small number of observations, to justify so general a conclusion. If the year 1900 were split into two halves,

it appeared that while the spring half had 30 per cent. more rain during daylight, the autumn half had 30 per cent. more during darkness, the same proportion as in the autumn half of 1899. It thus seemed quite possible that two complete years' observations might show no difference between daylight and darkness. He would also observe that if only the last month were to be omitted, an exactly opposite conclusion would have to be drawn. He would like to ask whether by sunrise and sunset at Seathwaite was to be understood the hour of appearance and disappearance of the sun above the mountains, or the time at which the sun might be supposed to rise if there were no mountains. Mr. Hooker would also be glad if Dr. Mill could inform him as to the number of rain-gauges within say 5 miles of Seathwaite, as it would appear that in that neighbourhood differences of 30 inches in the annual rainfall could be observed a couple of miles away; and it seemed to him that a network of gauges located there would be of great value in determining the effect of mountains upon the rainfall.

Mr. W. B. Tripp said that there was not much information on the subject published, but some years ago he had taken out the number of hours during which rain fell and the amount measured, for Kew, from the Meteorological Office publications for the 8 years 1887-94. From these figures he found that the wettest time of the day was between 2 and 3 in the afternoon with a total of 315 wet hours, and the driest period was between 10 and 11 in the morning with 182 wet hours. The greatest number of wet hours during the period was in 1892 with 1051 hours, while that at Seathwaite for 1900 was as much as 1194 hours. The rate of fall of rain was ·147 in. per day as compared with ·164 in. at Seathwaite. About 7 per cent more rain fell in the hours of daylight than in darkness, assuming the hours of daylight to be from 5 a.m. to 6 p.m., 12 hours.

He supplied the following summary of the number of days each of 24 hours had rain, and the total amount measured in the 8 years 1887-94, which he thought would be interesting:—

RAINFALL DATA FOR THE 8 YEARS, 1887-94, AT THE KEW OBSERVATORY.

Total number of hours in which rain fell:—

		Hours.		Days.		Weeks.
1892.	Highest . .	1051	=	43·8	=	6·3
	Mean . .	782·5	=	32·6	=	4·7
1887.	Lowest . .	603	=	25·1	=	3·6

Total number of days in which rain fell:—

1891.	Highest . .	188
	Mean . .	169·9
1893.	Lowest . .	158

Total rainfall measured:—

		Ins.
1892.	Highest . .	35·475
	Mean . .	25·015
1887.	Lowest . .	19·420

Total fall allocated to above number of hours:—

				Ins. per Hour.
1892.	Highest . .	$\frac{34·640}{1051}$	=	0·0330
	Mean . .	$\frac{23·544}{782·5}$	=	0·0301
1887.	Lowest . .	$\frac{17·970}{603}$	=	0·0298

Note.—Mr. Baldwin Latham states (see *Quart. Jour. R. Met. Soc.*, 1898) that he did not think that the total duration of rainfall during the whole of an average year would amount to more than three weeks, if all the time it was falling was added together.

The above figures give the number of hours in which rain fell, but not the exact duration of the time of falling.

Mr. Baldwin Latham said that the only fault he had to find was with the kind of recording gauge used, which recorded by steps, and was liable to considerable error, and the record would always have a tendency to lag behind the actual rainfall. He would have liked to see the results compared with an ordinary gauge set side by side with the recording instrument. In his own garden he had three self-recording rain-gauges, and at times there were considerable differences between them.

One instrument had been in use for 26 years without a break, but the newer ones were liable to fail at important times. He thought Mr. Tripp's figures were rather delusive, as the Meteorological Office figures gave only rainfall hours, and not the rate at which rain fell. The records of the Meteorological Office were of no value, as the rain recorded as falling in an hour may have fallen in one minute or sixty minutes. He did not know how the effect of daylight could influence the rainfall unless it was by the rise of temperature in the daytime. He thought the best way to measure the hours of darkness and light was to take "lighting-up" time, which was one hour after sunset and till one hour before sunrise. His own observations at Croydon did not quite concur with those at Seathwaite, for with him the heaviest rates of rainfall were those recorded in a short time and not spread over a long period. As a rule, long periods of rainfall resulted in a small rate of fall. He had noticed during the last few years that the average rate of rainfall was much less than 25 years ago, and wondered if there were any conditions of weather to account for it.

Dr. H. R. Mill, in reply, said that the full discussion of the London rainfall mentioned in the paper would, he feared, require more than a few months to make it ready for publication in its entirety.

With regard to the exception that was taken to the remark that 5 per cent more rain had been recorded during darkness than during daylight at Seathwaite, he could not assign any reason for it, nor affirm the relation as holding good generally, but only state the fact that it was so for the period considered taken as a whole. Most of the months showed the relation reversed, and it would require a number of years' observations before a definite general statement could be made.

He thought that the comparison of the rainfall with the wind observations referred to by Mr. Marriott gave interesting results. No doubt observations of the barometer and also of the micro-barograph would be equally valuable, if they could be applied to the records of individual showers.

Messrs. Negretti and Zambra's instrument answered its purpose fairly well, especially at Seathwaite, with its large and steady rainfall; it only failed to take account of the duration of very light rains. Mr. Symons had dealt very fully with the rainfall of the Lake District in *British Rainfall* for 1895, 1896, and 1897. There were a great number of rain-gauges within 5 miles of Seathwaite. He was glad to take the opportunity afforded by Mr. Hooker's question to explain that only a small number of rain-gauges in very remote places were maintained by the British Rainfall Organization, but that *British Rainfall* published all satisfactory records that were sent in, or could be obtained from other publications. Mr. Tripp's remark hardly bore on the subject in hand. He himself (Dr. Mill) was surprised at the long falls of rain at Seathwaite, showing the greater intensity, as the opposite certainly holds good in drier localities. He thought the long heavy falls must occur under cyclonic conditions. Thunderstorms were few in that neighbourhood, and an individual storm did not produce a rainfall bearing anything like the high proportion to the total annual fall which was usually found in the case of the summer thunderstorms of the south-east of England.

International Congress for the Study of Radiology and Ionization.

The first International Congress for the study of radiology and ionization will be held during the present year at Liège, between the 12th and 14th September (inclusive).

The Congress will be divided into two sections:

I. PHYSICAL SECTION.

1. *The Physics of Electrons*, including radiations of various kinds.
2. *Radioactivity*, and dependent transformations. The activity of waters and earths. Radioactive deposits.

(The above outlines of the work to be considered as suggestive rather than limiting. Our programme is intended, in fact, to include the study of all questions having to do with radioactivity.)

3. *Meteorological and Astronomical Phenomena*, and their relation to ionization and radioactivity.

II. BIOLOGICAL SECTION.

The programme governing the work of this section will include an examination of the physiological properties of various radiations and of radioactivity, and will consider their medical value and application. The method of procedure in this section will be determined upon by a special commission presided over by Profs. Bouchard and d'Arsonval, members of the Institut de France, and of the Academy of Medicine of Paris. The other members of this commission are, Drs. Béclère, Bergonié, Broca, Charpentier, Charrin, Danysz, and Oudin.

Besides this special commission, a general committee, composed of men notable for research work in matters of interest to our investigation, and presided over by M. Henri Becquerel, will examine, classify, and approve such reports, papers, and notes as may be offered. We particularly urge you to forward us, *with the least possible delay*, the manuscript of any contributions you contemplate making, as delay may make the printing of them impossible.

The titles of contributions should be forwarded us immediately, if possible.

Trusting that you will favour us with your co-operation, we remain, yours truly, on behalf of the Organising Committee,

DR. H. KUBORN, *President.*
DR. J. DANIEL, *General Secretary.*

REPORT OF THE COUNCIL

FOR THE YEAR 1904.

[Submitted to the Annual General Meeting, January 18, 1905.]

In presenting their Report the Council would point out that, while a satisfactory number of new Fellows has been elected during the past year, the number of deaths and resignations has also been considerable. The cost of the care of the increasing Library and of the Bibliographical work referred to below, as well as of the improvements recently introduced into the *Quarterly Journal* and the *Meteorological Record*, has more than absorbed the ordinary income of the Society during the past two years, and the deficit has been met by a sale of securities. The Council trust that it may not be necessary to curtail the work now being done, and they ask for the assistance of the Fellows in securing such an increase of membership as will provide the necessary income.

Amongst the exceptionally numerous deaths, the Council have to deplore the loss of Mr. E. E. Dymond and the Rev. F. W. Stow, both of whom were members of their body in former years, and have done good service in the cause of meteorology.

Patron.—The Council have the gratification of announcing that, in response to a letter signed by the Officers and Members of the Council, H.R.H. The Prince of Wales has honoured the Society by graciously consenting to become its Patron.

Committees.—The Council have been materially assisted during the year by several Committees, which have been constituted as follows:—

Editing Committee.—Messrs. F. Campbell Bayard, R. Bentley, R. Inwards, and R. H. Scott.

General Purposes Committee.—The President, Secretaries, Treasurer, Messrs. R. Bentley, W. H. Dines, and Baldwin Latham.

Kite Committee.—The President, Secretaries, Messrs. R. H. Curtis and W. H. Dines, and Capt. M. W. C. Hepworth.

Local Scientific Societies Committee.—The President, Secretaries, Treasurer, Messrs. H. N. Dickson, F. Druce, J. Hopkinson, and W. N. Shaw.

Meteorological Office Grant.—The Council feel that the advancement of Meteorological Science in this country depends so much on the encouragement afforded to research by the Government funds administered by the Meteorological Council, that they have followed with the greatest interest the proceedings of the Treasury Committee, as described in the Report recently published. The Council trust that, in the event of a reconstitution of the Meteorological Office, one member at least of any Advisory Committee which may be formed will be a representative of the Royal Meteorological Society. An analogous case is the relation of the Royal Astronomical Society to the Board of Visitors of the Royal Observatory, Greenwich.

Lectures.—At the request of the Council, a lecture on "Water-Vapour,"

illustrated by numerous lantern slides and experiments, was delivered on March 16 by Mr. R. H. Curtis.

An address of exceptional interest on "Meteorological Observing in the Antarctic Regions," illustrated by numerous lantern slides, was delivered on November 16 by Lieut. C. Royds, R.N., of the *Discovery*, who was in charge of the meteorological work of the National Antarctic Expedition.

Howard Medal.—The Howard Silver Medal to the cadets of the Nautical Training College, H.M.S. *Worcester*, was awarded to Cadet E. J. A. Lawson for the best essay on "The Barometric Conditions over the Oceans."

Kite Committee.—The work of this Committee has been continued. The British Association granted £50 towards the expenses. The Admiralty placed at the disposal of the Committee, through the Royal Society, H.M.S. *Seahorse*, 800 tons, for the purpose of carrying on kite observations off Crinan during the summer. Mr. Dines was kind enough to devote six weeks to the superintendence of the work on board, and kite ascents were made almost every day, the average height attained being one mile. Mr. Dines hopes to be able to communicate the results to the Society at an early date, in the form of a paper. The Council again desire to acknowledge their deep indebtedness to Mr. Dines and his two sons, for the time and attention they have devoted to the work, and for the skill and success with which they have overcome innumerable, and often unforeseen, difficulties. The British Association has made a further grant of £40 towards carrying on the observations during the ensuing year.

Local Scientific Societies Committee.—At the suggestion of Mr. Druce, the Council appointed a Committee "to consider by what means the study of Meteorology can be brought before local Scientific Societies, and, if thought feasible, to prepare a scheme for consideration of the Council." The Committee has collected a certain amount of information, which has been embodied in a Report now under the consideration of the Council.

Optical Convention.—At the request of Dr. R. T. Glazebrook, who stated that it was proposed to hold an Optical Convention in this country, and invited the Society to support the scheme by nominating a representative to serve on the General Committee, the Council appointed Mr. Inwards as the Society's representative.

Kew Observatory.—On the invitation of Dr. R. T. Glazebrook, the Council visited Kew Observatory on June 8, and were very hospitably entertained.

Research Fund.—This fund is represented by the sum of £68 : 12 : 9, 2½ per cent Consols. The Council are anxious that it should be augmented, as, having regard to the small sum at the disposal of the Kite Committee for the ensuing year's experiments, it may prove to be inefficient.

Meetings.—With the exception of those in May and June, which took place in the Society's rooms, the Meetings were held as usual, by the courtesy of the President and Council of the Institution of Civil Engineers, at their house in Great George Street, Westminster.

Quarterly Journal.—The volume for 1904 consists of 360 pages, and contains the papers read at the meetings of the Society, with the discussions which followed, numerous notices of meteorological interest, and also a translation of Dr. H. H. Hildebrandsson's Report to the Permanent International Meteorological Committee on "The International Observations of Clouds." The recently added section of "Meteorological Literature" has been continued.

Meteorological Record.—Four parts have been issued during the year, bringing this publication up to June 1904.

Stations.—Observations have been accepted from the following new stations:—Carrick-on-Suir, Co. Kilkenny; Harrogate, Yorkshire; Keswick, Cumberland; Kingstown, Co. Dublin; Porthcawl, Glamorganshire; and Raunds, Northamptonshire.

Inspection of Stations.—All the stations south of latitude 54° N., and west of longitude 2° W., as well as such other stations as could be conveniently visited, were inspected and found to be, on the whole, in a satisfactory condition. Mr. Marriott's Report will be found in Appendix II., p. 247.

Phenological Report.—This valuable Report, the thirteenth prepared by Mr. E. Mawley, was read by him at the February meeting. The Society owes its best thanks to Mr. Mawley for his persevering labours in collecting and discussing the returns.

Library.—The rearrangement and cataloguing of the Library has been completed. The work has been extremely arduous. The Library now consists of the following:—Volumes, 8420; Pamphlets, 11,499; Maps and Charts, 210; Manuscripts, 790; and MS. Observations, 140. The revision of the Catalogue is now being taken in hand, as opportunity occurs, but little progress has been made, as the Library work has grown to such an extent in recent years, owing to the preparation of the cards for the Bibliography, and for the *International Catalogue of Scientific Literature*, etc., that the time of the Librarian is fully occupied.

Meteorological Bibliography.—During the year, 5956 cards have been prepared for the Society's Bibliography. This consists of the titles of all books, pamphlets, papers, and articles bearing on Meteorology of which any notice can be found. In addition to the above, 761 catalogue cards of the titles of works bearing on Meteorology, published in the British Isles, have been prepared for the *International Catalogue of Scientific Literature.*

The Council have to express their recognition of the courtesy of the editors of the *Meteorologische Zeitschrift*, Berlin, and of the *Geographical Journal*, London, for supplying advance proofs of their valuable monthly Bibliographies.

The Council desire once more to remind the Fellows and others that it would enhance the value of the Bibliography if a copy or notification of all meteorological books and papers of which they may be the authors were sent to the Society.

For Continuation of Report of the Council, see page 246.

APPENDIX

STATEMENT OF RECEIPTS AND EXPENDITURE

RECEIPTS.

Balance from 1903		£93 6 5
Subscriptions for 1904	£811 0 0	
Do. for former years	62 14 0	
Do. paid in advance	38 0 0	
Life Compositions	63 0 0	
Entrance Fees	41 0 0	
		1015 14 0
Meteorological Office—Copies of Returns	£101 7 7	
Do. Grant towards Inspection Expenses .	25 0 0	
		126 7 7
Dividends on Stock (including £48 : 1 : 11 from the New Premises Fund)		149 7 0
Sale of Publications, &c.		34 10 4
Sale of £230 Western Australia Government 3 per cent Inscribed Stock .		200 14 0
		£1619 19 4

I.

FOR THE YEAR ENDING DECEMBER 31, 1904.

EXPENDITURE.

Journal, &c.—		
Quarterly Journal, Nos. 127 to 132	£262 9 3	
Illustrations	36 17 10	
Authors' Copies	18 1 6	
Meteorological Record, Nos. 88 to 93	127 17 6	
		£445 6 1
Printing, &c.—		
General Printing	£20 13 3	
List of Fellows and Observation Books	20 10 0	
Stationery	18 2 2	
Books and Bookbinding	25 9 0	
		84 14 5
Office Expenses—		
Salaries	£544 17 6	
Rent	212 0 0	
Coals, Lighting, and Insurance	15 11 4	
Furniture and Repairs	5 18 11	
Postage	73 15 1	
Petty Expenses	19 2 10	
Refreshments at Meetings	14 2 10	
Lecture	10 10 0	
		895 18 6
Observations—		
Inspection	£59 10 7	
Observers	10 3 0	
Instruments	2 0 10	
		71 14 5
		£1497 13 5
Balance—		
At Bank	£111 15 3	
In hands of the Assistant-Secretary	10 10 8	
		122 5 11
		£1619 19 4

Examined, compared with vouchers, and found correct,

T. P. NEWMAN, }
FREDc. GASTER, } *Auditors.*

January 10, 1905.

APPENDIX

ASSETS AND LIABILITIES

LIABILITIES.

To Subscriptions paid in advance	£38 0 0	
,, Rent for quarter ending December 25, 1904	53 0 0	
,, Meteorological Record, No. 94	17 18 6	
,, General Printing	0 11 0	
,, Illustrations	0 15 3	
		£110 4 9
,, Excess[1] of Assets over Liabilities		3412 2 1
		£3522 6 10

[1] This excess is exclusive of the value of the Library, the Stock of Publications, and the Symons Bequest and Bibliography.

WM. MARRIOTT, *Assistant-Secretary.*

NEW PREMISES FUND,

Amount paid to the Society's Fund towards the rent of rooms at 70 Victoria Street	£48 1 11

RESEARCH FUND,

Balance from 1903 (including £91 : 12 : 6 from Grant for the Kite Observations)	£92 18 0
Interest on Investment	1 12 8
Anonymous Donation for Kite Observations	25 0 0
Sale of Kite, &c.	3 3 0
	£122 13 8

I.—continued.

ON DECEMBER 31, 1904.

ASSETS.

By Investment in Great Central Railway 4½ per cent Debenture Stock, £800 at 130¾	£1046 0 0	
,, Investment in New South Wales 4 per cent Inscribed Stock, £654 : 18s. at 106¼	695 16 8	
,, Investment in London & North-Western Railway Consolidated Stock, £400 at 156¼	625 0 0	
,, Investment in London & North-Western Railway 4 per cent Preference Stock, £12 at 120	14 8 0	
,, Investment in 2½ per cent Annuities, £231 : 11 : 9 at 87⅝ .	202 18 7	
		£2584 3 3
,, Subscriptions unpaid, estimated at	£60 0 0	
,, Entrance Fees unpaid	9 0 0	
,, Interest due on Stock	54 18 3	
,, Meteorological Office—Weekly Returns, 1904 . .	28 19 0	
		152 17 3
,, Furniture, Fittings, &c.	£526 12 2	
,, Instruments	136 8 3	
		663 0 5
,, Cash at Bank of England	£111 15 3	
,, Cash in hands of the Assistant-Secretary . . .	10 10 8	
		122 5 11
		£3522 6 10

Examined, and securities seen at the Bank of England,

January 10, 1905.

T. P. NEWMAN, }
FRED^C. GASTER, } *Auditors.*

DECEMBER 31, 1904.

Interest received on Investment	£48 1 11

Note.—The Society holds on account of the Fund £1443 : 7 : 9 South Australian 3½ per cent Inscribed Stock.

Examined,

January 10, 1905.

T. P. NEWMAN, }
FRED^C. GASTER, } *Auditors.*

DECEMBER 31, 1904.

Purchase of £3 : 5 : 11 Consols at 88¼	£2 18 2
Expenses connected with the Kite Observations	71 9 8
	£74 7 10
Balance of Grant for Kite Observations	48 5 10
	£122 13 8

Note.—The Society holds on account of the Fund £68 : 12 : 9, 2½ per cent Consols.

Examined,

January 10, 1905.

T. P. NEWMAN, }
FRED^C. GASTER, } *Auditors.*

APPENDIX

SYMONS MEMORIAL

Balance from 1903	£24 11 8
Interest received on Investment.	18 17 2
	£43 8 10

Fellows.—The changes in the number of Fellows are given in the following table:—

Fellows.	Annual.	Life.	Honorary.	Total.
1903, December 31	497	151	19	667
Since elected . . .	+42	+ 1	...	+43
Reinstated	+ 3	+ 1	...	+ 4
Compounded . . .	− 1	+ 1	...	0
Deceased	−13	−10	...	−23
Retired	−23	...	...	−23
Lapsed	− 5	...	...	− 5
Struck off	− 5	...	...	− 5
1904, December 31	495	144	19	658

Deaths.—The Council have to announce with much regret the deaths of twenty-three Fellows, viz.:—

R. Hawksworth Barnes, B.A., F.L.S.	elected	June 15, 1864.
William Berridge	„	Nov. 17, 1897.
William Alfred Browne, M.A., LL.D., F.R.G.S.	„	Jan. 16, 1901.
William Digby, C.I.E.	„	Nov. 19, 1902.
Edward Ernest Dymond, J.P.	„	Apr. 18, 1866.
Arthur John Leopold Evans	„	June 20, 1900.
Franklen George Evans, J.P., M.R.C.S., F.R.A.S.	„	Mar. 21, 1866.
Robert Gordon	„	Nov. 21, 1877.
Thomas Merthyr Guest, J.P., D.L.	„	Nov. 18, 1903.

I.—continued.

MEDAL FUND, 1904.

Gold Medal, 1904	£25 0 0
Cash at Bank of England, December 31, 1904	18 8 10
	£43 8 10

Note.—The Society holds on account of this Fund £630 Cardiff Corporation Redeemable Stock, 3 per cent.

Examined,

January 10, 1905.

T. P. NEWMAN,
FREDC. GASTER, } *Auditors.*

Charles Kelly, M.D., F.R.C.P., D.P.H.	elected	Nov. 16, 1898.
William Joseph Kingsbury, M.Inst.C.E.	„	June 15, 1864.
Lieut.-Col. Henry Sollers G. S. Knight, F.R.A.S.	„	Dec. 17, 1873.
Stratton Collings Knott	„	June 19, 1895.
Charles Augustus Langton, M.A., J.P.	„	Nov. 18, 1868.
Stephen Albert Marshall, J.P.	„	Feb. 21, 1900.
William Beswick Myers-Beswick, M.Inst.C.E., F.G.S.	„	Dec. 18, 1889.
Francis Newman	„	Feb. 19, 1879.
Capt. Moses Parry	„	Nov. 17, 1880.
Frank Russell, F.R.G.S.	„	June 17, 1891.
Rev. Maurice Allen Smelt, M.A., F.R.A.S.	„	Nov. 27, 1855.
Rev. Fenwick William Stow, M.A.	„	Mar. 21, 1866.
William Henry Tyndall	„	Feb. 15, 1882.
Rev. Charles Wolley-Dod, J.P.	„	Dec. 16, 1896.

APPENDIX II.

INSPECTION OF THE STATIONS, 1904.

All the stations in the west and south-west were inspected during the summer, and were found to be generally in a very satisfactory condition. The observers in almost all cases take a keen interest in the work.

The number of thermometers tested was 189, and changes of zero were found to have taken place in 36, which were distributed as follows: Dry-bulb, 10; Wet-bulb, 12; Maximum, 3; Minimum, 3; Grass Minimum, 3; and Earth Thermometers, 5.

At two stations the observers had inadvertently changed some of the thermometers, and had consequently been applying the wrong corrections. I discovered these changes when comparing the numbers on the thermometers with those on my notes, previous to testing the instruments.

The readings of the maximum thermometer at Northwich had often been reported about 45° during the winter months, when the temperature was really much lower. I made a special point of inquiry into this matter. By testing the thermometer in salt and ice, I found that at low temperatures the mercury was liable to break away and run up the tube to about 45°. The instrument therefore required to be mounted considerably on the incline.

A few of the maximum thermometers needed a good deal of shaking in order to set them. It is probable that occasionally the readings from these thermometers may have been too high, owing to the instruments not being fully set. In all these cases I urged the observers always to see that the readings of the maximum and minimum when set practically agreed with that of the dry-bulb.

Nearly all the observers and their deputies agreed with me in the readings of the various instruments. Fourteen thermometers were, however, not correctly read, the errors being 5° five times, 10° three times, 1° five times, and 4° once.

At Cheltenham the observer, a few months ago, cleaned the mercury in the cistern of the Fortin barometer, and in so doing let some air up the tube. When I called his attention to the fact that the barometer readings were too low, he sent the instrument to the maker for rectification, but in transit the tube was broken! A new tube, consequently, had to be put in the barometer. It is very desirable that observers should not attempt to clean the mercury in their barometers, but should hand their instruments to the makers to be properly dealt with.

WM. MARRIOTT.

October 15, 1904.

NOTES ON THE STATIONS.

ABERYSTWITH, *July* 15.—The Glaisher rain-gauge in Dr. Thomas's garden needed repairing as the flange of the funnel had been broken off, and there was consequently a liability for the rain to trickle down the outside into the can inside. The mercury in the maximum thermometer had a tendency to run up the tube, and the water receptacle was too near the wet-bulb. I therefore recommended a rearrangement of the thermometers in the screen. The Jordan sunshine recorder was not in proper adjustment, as it was set for lat. 44° instead of 52½°. A promenade walk and drive have been constructed round the outside of the Castle grounds, and consequently the ground has been somewhat curtailed. The exposure is very bleak. I recommended Dr. Thomas, if possible, to put up a thermometer screen in his own garden.

ARDGILLAN, *July* 2.—This station was in good order. The barometer was apparently usually set too high, the observer leaving a gap between the vernier and the top of the mercury. I recommended that the maximum thermometer be mounted more inclined to prevent the mercury running up the tube, and also that back plates with a hole and slot be put on the maximum and minimum. On comparing the thermometers it was found that the dry, wet, and 6 ft. had gone up 0°·2, and the 1 ft., 2 ft., and 4 ft., 0°·1.

ASHBURTON, *August* 20.—The thermometer screen had been mounted on new posts. On comparing the thermometers it was found that the dry and wet had both gone up 0°·1, and the minimum 0°·3.

BATH, *September* 7.—The grass minimum had about 3° of spirit up the tube. The trace on the sunshine card was about 10 minutes slow. The new large hotel on the east cuts off a little of the early morning sunshine, the tower making an angle of 8°.

BELMONT, HEREFORD, *September* 2.—On comparing the thermometers it was found that the dry and wet had both gone up 0°·2. I recommended a rearrangement of the thermometers in the screen. A new maximum thermometer had been obtained some time ago. As this requires a great deal of shaking to set it, I urged the observer always to see that it practically agreed with the dry-bulb and minimum when set. The grass minimum had a little spirit up the tube.

CAHIR, *July* 13.—The instruments had been moved some time ago to Bengurrah, about a mile north-west of the former station. They are placed on a lawn close to a field, and have a good exposure. On comparing the thermometers it was found that the wet-bulb had gone up 0°·1, and the minimum gone down 0°·2.

CARRICK-ON-SUIR, *July* 13.—At the request of Lieut.-Col. Villiers Stuart I went to see his station at Castletown, 3 miles north-east of Carrick. The Stevenson screen is in the kitchen garden. I recommended that it be moved to the south side of the path, and that a grass plot be put down. The situation will then be very good. There are two rain-gauges near the house, one a very deep Snowdon, and the other a shallow funnel with a wooden frame. I recommended that the former be placed in the garden near the thermometer screen.

CASTLE HILL, FILLEIGH, *August* 27.—A tree on the west had been cut down some time ago, so the exposure is now more open than formerly. This is the only station at which I have seen scarlet cotton used for the conducting thread of the wet-bulb.

CHELTENHAM, *September* 5.—There was a little spirit at the top of the tube of the grass minimum. I recommended that the grass minimum be more exposed. The Jordan sunshine recorder was in good adjustment. The Robinson anemometer was not working very satisfactorily. The observer some time ago in cleaning the mercury of the Fortin barometer let some air get into the tube. When I called his attention to the fact that the barometer was reading too low, he sent the instrument to the maker for rectification. In transit, however, the tube was broken, consequently a new tube had to be put into the barometer. The instrument is now satisfactory.

CHESTER, *July* 20.—On comparing the thermometers it was found that the dry had gone up 0°·2. I did not see the Rev. J. C. Mitchell, as he was away for holidays. The observations were not being taken, as the deputy had failed.

CULLOMPTON, *August* 18.—On comparing the thermometers it was found that the dry had gone up 0°·2. The grass minimum had some spirit up the tube. Mr. Turner has a glass shade over the sunshine recorder. Air is permitted to get inside the shade, so there is no steaming on the glass. There is a possibility of a tree in a neighbouring garden to the east-south-east soon intercepting the morning sunshine.

DUBLIN, *July* 12.—The instruments were in the same position as at the previous inspection. I recommended that the trees on the south-east and north-west be cut back. A new station had been started at Trinity College, and is under the charge of Mr. A. Moore. In addition to the usual instruments, there are earth thermometers at 1 ft. and 4 ft., and also a Campbell-Stokes sunshine recorder, the latter being placed on the roof of the Magnetic Observatory, where Dr. Lloyd formerly observed. I suggested that the recorder be moved to another part of the roof in order to have a better exposure.

FALMOUTH, *August* 25.—This station was in good order. The ball of the sunshine recorder is cemented to the pedestal. The minimum thermometer had 0°·4 of spirit at the top of the tube. The rainfall is taken at 10.30 a.m. for Observatory purposes.

GWERNYFED PARK, *September* 3.—There had been a change of observer a few months previously. I gave the head gardener, who is the new observer, full instruction in the working of the instruments and in the methods of observation. There was a little spirit at the top of the tube of the minimum. I recommended that cross-pieces be put on the posts of the thermometer screen to strengthen them.

HAVERFORDWEST, *August* 30.—I recommended that a new water receptacle be used for the wet-bulb—a glass wider at the top than at the bottom, so as not to burst in frost, and that it have a cover with a hole in it. As the sun in winter does not reach the black bulb *in vacuo* I recommended that the thermometer be removed to the top of the reservoir near the sunshine recorder. As mentioned in the last report, the sunshine recorder is of a Swiss make, and apparently does not give such a good record as those of English make.

HOYLAKE, *July* 20.—This station is well arranged, and the instruments have a good exposure. I discovered that the dry and wet thermometers had been transposed for more than a year, and that consequently the wrong corrections had been applied to their readings. On comparing the thermometers it was found that the wet had gone up 0°·1, and that the minimum and grass minimum had both gone down 0°·2. The sunshine cards had not been measured along the trace, but at a different part of the card, and so the amounts were during some portion of the year too much and during other portions too small.

ILFRACOMBE, *August* 27.—On comparing the thermometers it was found that the dry bulb had gone up 0°·2. The pipe of the rain-gauge funnel was broken off and needed resoldering.

ILTON, *August* 17.—This station was in good order. On comparing the thermometers it was found that the minimum had gone up 0°·1 and the 1-ft. earth thermometer had gone down 0°·3.

KESWICK, *July* 22.—I found that Mr. Dawson had carried out the suggestions which I had made at my former visit, and that he had equipped a very good station. On a grass plot 13 ft. square was placed the Stevenson screen, grass minimum, 4 earth thermometers, black and bright bulb thermometers *in vacuo*, and rain-gauge. I recommended a rearrangement of the thermometers in the screen, and also that the thermometers be read to tenths instead of whole degrees. The grass minimum had some spirit up the tube. Both the black and bright bulb thermometers had moisture in the outer jackets, which condensed on the glass. Vacuum gauges were attached to each instrument.

KILLERTON, *August* 18.—The thermometers are now placed in a Stevenson screen, which has a good exposure.

KINGSTOWN, *July* 13.—The instruments are in the same position as at my former visit. The thermometer screen is much lower than usual. The door also has a pane of glass in order to permit people in the park to see inside the screen. The observations are taken by the curator of the park. The sunshine recorder, which has Curtis's arrangement, is placed on the roof of the municipal building. The trace was not running parallel with the card.

LLANBEDR, *July* 7.—This station was in good order.

LLANDUDNO, *July* 8.—This station was in good order. On comparing the thermometers it was found that the dry and wet had gone up 0°·2. The sun-

shine recorder is mounted on an iron column. The spot of light was on the noon line of the card at 12.0 local time. The barometer is mounted in the Sanitary Inspector's office at the Town Hall, but it is reading ·047 in. too low.

LLANERCHYMEDD, *July* 9.—There was no change in the thermometers. The conducting thread for the wet-bulb was much too thick and was not acting properly. I recommended that wooden rails be fixed to the posts of the thermometer screen to make it more firm. I found that the omissions in the returns were due to forgetfulness to observe at the proper time. I urged the observer not to omit these, but to enter the time against any readings which were not taken at 9 a.m.

MALVERN, *September* 3.—There was no change in the zeros of the thermometers. I recommended that a new water receptacle be used instead of a small bottle, and also that a better conducting thread be employed. As the mercury in the maximum had a tendency to run up the tube, I suggested the thermometer be mounted more inclined.

NEWQUAY, CORNWALL, *August* 24.—The thermometer screen is in a small railed-off enclosure, and the rain-gauge in a separate enclosure. During last year the rain-gauge had been tampered with, and the result vitiated. In consequence of this a second rain-gauge was started on the reservoir, but owing to the distance from the observer's house it could not be examined each day. Since the old gauge has been repaired and placed in a special enclosure, the rainfalls from the two gauges have practically agreed. The sunshine recorder is mounted on a brick pier on the top of the reservoir. The sunshine trace was not running parallel with the card.

NORTHWICH, *July* 19.—On comparing the thermometers it was found that the wet had gone up 0°·2. I tested the working of the maximum thermometer in salt and ice, and found that at low temperatures the mercury was liable to break away and run up the tube to about 45°. This explained many of the high readings reported during the winter. I recommended that the thermometer be mounted considerably on the incline.

PAINSWICK, *September* 6.—This station is about 3½ miles north of Stroud. The instruments are placed in the kitchen garden, and are on the north side of the valley, on ground sloping considerably from north to south. The water receptacle was too near the wet-bulb, and the muslin needed changing. I recommended a rearrangement of the thermometers in the screen.

PENZANCE, *August* 26.—The Town Council having put up a fountain on the grass plot where the thermometer screen and rain-gauge were placed, it became necessary last year to remove the instruments to the site which they formerly occupied. The exposure is consequently more confined, as there are high trees all round, except on the north, where stands the Subscription Library. There is also a sloping bank on the north. The Campbell-Stokes and Jordan sunshine recorders are mounted on the roof of the Market Hall and have a good exposure.

PIRBRIGHT, *September* 20.—On comparing the thermometers it was found that the wet-bulb had gone up 0°·1 and the maximum 0°·2. As the maximum requires a considerable shaking to set it, I recommended that it be mounted more inclined. The observations are taken by a corporal, except in the winter, when they are taken by Quarter-Master Sergeant Elwick. During July the wet-bulb had been allowed to get nearly dry, and the maximum and minimum thermometers, although read, were not set.

PORTHCAWL, *August* 31.—The instruments are placed in a railed-off enclosure in the church ground where there is a good exposure. As the post

carrying the Jordan sunshine recorder was too near the rain-gauge, I recommended that it be moved farther away, close to the thermometer screen. As water frequently got into the cylinder of the Glaisher rain-gauge when taking off the funnel, I advised that 4 holes be made in the outer flange to prevent the water from accumulating there. I gave the observer instruction in the measurement of sunshine records and in reading the thermometers to tenths of degrees.

PRINCETOWN, *August* 22.—This station was in good order. The Governor of the prison takes great interest in the observations.

RODEN, *July* 4.—The thermometer screen required painting. The water receptacle was too far from the wet-bulb, and lamp wick was used instead of muslin and cotton. As some apple-trees were growing up near the rain-gauge, I recommended that it be moved about 10 ft. farther south-west. The amount of cloud had been under-estimated. On comparing the thermometers it was found that the maximum had gone down 0°·4.

ROSS, *September* 2.—The muslin on the wet-bulb was too thick and baggy. I recommended that the posts of the thermometer screen be strengthened. On comparing the thermometers it was found that the dry had gone up 0°·1, and the wet gone down 0°·2. As trees and plants have grown up very much in the neighbourhood of the rain-gauge, I recommended that three trees be topped.

ROUSDON, *August* 16.—On comparing the thermometers it was found that the wet-bulb had gone up 0°·1. The minimum had 0°·4 of spirit up the tube. The sunshine trace was not running parallel with the card, as the ball was too high in the frame. The instrument was subsequently readjusted.

RUMNEY, *August* 31.—This station was in good order. On comparing the thermometers it was found that the dry and wet had gone up 0°·1, and the minimum gone down 0°·2.

RUTHIN, *July* 18.—This station is at the Vale of Clwyd Sanatorium, Llanbedr Hall, 2½ miles east of Ruthin, and 450 ft. above sea level. The ground rises on the east to a point 1800 ft. above sea level. The Jordan sunshine recorder is mounted on a post in a field. There are numerous trees about, and those on the eastern side cut off some of the morning sunshine. I recommended that the recorder be moved some distance further south-west, and that it be raised to about 15 ft. above the ground.

SALCOMBE, *August* 23.—I could not detect any sign of a bubble in the spirit of the minimum thermometer. During the winter the readings of this thermometer had been deranged owing to the formation of a bubble on the lower side of the index needle. The sunshine recorder, which has Curtis's arrangement, was in good adjustment. It is placed on a slab on the top of the reservoir.

SEATHWAITE, *July* 22.—New hinges were required for the door of the screen. I recommended that wooden rails be fixed to the posts in order to strengthen the screen. I gave Mrs. Jackson, the new observer, instruction in the use of the instruments and in the method of observing.

SHAFTESBURY, *August* 15.—There was no change in the zeros of the thermometer. I recommended that the muslin round the wet-bulb be kept tight and not baggy. I also suggested a rearrangement of the thermometers in the screen.

SIDMOUTH, *August* 17.—The instruments were in good condition. The Jordan sunshine recorder is mounted on a movable frame in order to elevate it above the ground. The trees to the east intercept a little of the morning sunshine. Possibly also a tree on the south-west may affect the winter sunshine.

TEIGNMOUTH, *August* 19.—The instruments have been moved from the south-western corner of the Den to a plot on the eastern side, about 300 ft. from the embankment wall. This was rendered necessary by the spray being blown over the former site during severe gales, mentioned as most likely to occur in my previous report. The grass minimum had some spirit at the top of the tube. It is contemplated to have a sunshine recorder.

THAMES DITTON, *November* 10.—This station was in good order. On comparing the thermometers it was found that the dry had gone up 0°·2, and that the grass minimum had gone down 0°·2.

TORQUAY, *August* 19.—This station was in good order. On comparing the thermometers it was found that the dry and wet had both gone up 0°·2. The sunshine recorders are placed on the roof of one of the shelters of the Princess Pier. I recommended that the Jordan recorder be raised about 6 ins., so as to be above the Campbell-Stokes recorder.

TOWYN, *July* 6.—This station is about a mile from the sea on the west, 5 miles from hills on the north, and 3 miles from hills on the east. The instruments are placed in a railed-off enclosure at the end of a lawn. I recommended that the enclosure be enlarged, and that the rain-gauge be moved farther from the railings. The exposure is open, the ground being only 10 ft. above sea level. The water receptacle was too near the wet-bulb; in fact the water was touching the bulb. I recommended a rearrangement of the thermometers in the screen. The Jordan sunshine recorder was not in proper adjustment, being considerably out in time. It is proposed to add a 4-ft. earth thermometer.

WESTON-SUPER-MARE, *September* 1.—The instruments are placed in a railed-off enclosure in the churchyard at the back of the Town Hall. I recommended a rearrangement of the thermometers in the screen. The rain-gauge has a shallow funnel, so I suggested that a deeper one be provided. There were two black-bulb solar thermometers, one with the bulb and 1 inch of the stem coated with lampblack, and the other with only the bulb blackened, beside which there was some water in the outer glass jacket. The Campbell-Stokes sunshine recorder, which is of the Universal pattern, is on the roof of the Town Hall. The ball was too high, and the instrument was set for lat. 50° instead of 51½.° The frame was also liable to shift on its pivot. As I could not get a suitable pair of pliers to clamp it, I explained how it should be done. The measurement of the sunshine had not been made along the trace of the burn.

WHITCHURCH, TAVISTOCK, *August* 22.—This station was in good order. On comparing the thermometers it was found that the maximum had gone up 0°·3. Mr. Glyde is very keen on all meteorological matters.

WOOLACOMBE, *August* 29.—The instruments were in good order. The barometer was not hanging quite perpendicularly; the board needed wedging out from the wall at the top. The sunshine recorder was in good adjustment. The hills on the east-north-east, and on the east-south-east to south-east make an angle of 7°, and so may intercept a little of the very early sunshine. I urged the desirability of there being a trained deputy observer.

APPENDIX III.

OBITUARY NOTICES.

EDWARD ERNEST DYMOND was born in Exeter. He was educated at Grove House, Tottenham, and on his return home he was articled to a solicitor at Exeter. He subsequently went to London, and resided for

some years in the Temple, working in his profession. He entered into partnership at Highworth, Wiltshire, but his health failing, he relinquished his profession, and soon after went to Wellington, Somerset, where he devoted himself chiefly to scientific pursuits. In 1870 he purchased an estate at Aspley Guise, Bedfordshire, where he resided until his death.

Mr. Dymond became a Justice of the Peace in 1879, and a Deputy Lieutenant in 1894, when he was appointed High Sheriff for the county. He was a member of the first Bedfordshire County Council, and worked most assiduously as first Chairman of the Finance Committee. He afterwards became Vice-Chairman of the County Council.

Mr. Dymond's interest in meteorology began early, for as a schoolboy rain-gauge measurements and thermometer records were put in his charge. As soon as he had a house of his own he commenced the series of meteorological observations which, on an extended scale, he carried on to the very last. He was elected a Fellow of this Society on April 18, 1866, and served on the Council from 1879 to 1882, being Vice President in 1880-81. He was appointed one of this Society's Delegates to the Lightning Rod Conference in 1878, and rendered considerable assistance in the preparation of its Report. On April 15, 1904, while taking the meteorological observations in the morning, he was struck down with a sudden attack of paralysis, and died on April 19.

Franklen George Evans was born in 1827, and was the fourth son of Dr. Edward Evans, who was at one time the only surgeon in Cardiff, and who was a native of the town, his father being an old resident also. Mr. Franklen George Evans, whilst at St. Bartholomew's Hospital in 1849, obtained his M.R.C.S. and L.S.A., and continued his connection with St. Bartholomew's till 1850, when he succeeded Mr. A. B. Andrews as house surgeon of the Cardiff Infirmary.

In 1852 he was offered, and accepted, the appointment of surgeon and medical officer to the Pentyrch Iron Works and Colliery and the tinplate works at Melingriffith. When the business at the Pentyrch works fell off, and the West of England Bank, which had financed the works for some time, ceased payment in 1878, the works were closed, and Dr. Evans obtained the appointment of surgeon to the Aberpergwm Colliery. With his first and second wives he received considerable property, and he soon afterwards retired from professional pursuits and removed to Llwynarthan, Castleton, where he died in 1904.

Dr. Evans was not only a man of considerable attainments, but one who had so arranged his studies—studies that had extended over a long series of years—that he was regarded by some as a cyclopædia on many scientific questions. For years he had made astronomy, mineralogy, and meteorology his favourite studies. He possessed a large and valuable astronomical telescope, which he in after years presented to the Cardiff Corporation. In 1867 he was one of the most active in establishing the Cardiff Naturalists' Society, which two years after numbered 250 members. He took a great interest in this society, and liberally contributed papers, which were published in the records of its proceedings. He was the author of several papers on meteorology, and was a contributor to several scientific publications. He was a good musician, could play well, and he published some musical compositions in early life, which were favourably criticised.

In 1880 he was appointed one of the directors of the Rhymney Railway Co., and subsequently was elected chairman. He was also a director of the Cardiff Gas Co., Pontypridd Water Works Co., etc.

He was elected a Fellow of this Society on March 21, 1866.

ROBERT GORDON was born at Liverpool in 1841. He was educated at the Liverpool Institute, and afterwards trained in engineering works. He studied hard in his leisure hours and went in for the Civil Service examination at the London University, where he gained the highest marks. He was soon afterwards appointed Assistant Engineer in the Public Works Department, Burma. He remained under the Indian Government until 1889, when he retired, being then Executive Engineer and Superintendent of Works.

He designed and constructed the Irrawaddi River Embankments almost from the beginning. These works were most successful in protecting great areas from inundation and securing a large yearly revenue to the Government. During this time he wrote several professional works, and his *Report on the Irrawaddi River* received very favourable notice.

After retiring from the Public Works Department he did some surveying in Mandalay for the Ruby Mines Company, and then went to Siam as Chief Engineer to the King of Siam. His health failing somewhat at this time, he went to Australia for three years and did professional work there. He came back to England ill in 1899 and died of gradual paralysis in April 1904.

He was for many years a Member of the Institution of Civil Engineers and of the Institution of Mechanical Engineers, and was a Fellow of the Royal Geographical Society.

He was elected a Fellow of this Society on November 21, 1877.

DR. CHARLES KELLY, who died suddenly at Worthing on June 16, 1904, at the age of 59 years, had a distinguished professional career. He obtained his degree of Bachelor of Medicine in 1866, and in the same year became a Member of the Royal College of Surgeons. In 1867 he not only took his degree of Doctor of Medicine, but also secured the Gold Medal; and in 1880 he was elected a Fellow of the Royal College of Physicians. He was also a Fellow of King's College, London, and was for a considerable time Professor of Hygiene and Public Health.

In March 1874 he was appointed Medical Officer of the Combined Sanitary District of West Sussex, which office he continued to hold until his death.

Dr. Kelly was also greatly interested in Meteorology, and superintended the Worthing Corporation Climatological Station. He rendered valuable assistance to the West Sussex district, and especially to Worthing, during the epidemic in 1893.

He was elected a Fellow of this Society on November 16, 1898.

STRATTON COLLINGS KNOTT died of sunstroke on January 28, 1904, whilst on a boating excursion off Majunga, West Coast of Madagascar. He was the son of the Rev. J. C. Knott, of Combe Hill House, Monkton Combe, Bath. He was born at the Rectory, Stanford le Hope, Essex, on May 30, 1856.

Mr. Knott was British Vice-Consul for the West Coast of Madagascar from 1887 to the time of his death. He was also the agent of Lloyd's, London, and the correspondent of Messrs. Procter Brothers of London and Madagascar.

He built an observatory at Majunga, and furnished observations and information to the Government of Madagascar and the Royal Meteorological Society, London. For his services in this direction Mr. Knott was made "Officier de l'Académie" by the French Government, on the recommendation of General Gallieni, the Governor-General of the island.

When the French landed at Majunga, the soldiers seized his instruments as Malagasy *curios*. He afterwards got them restored.

He was elected a Fellow of this Society on June 19, 1895.

STEPHEN ALBERT MARSHALL was born near Leeds, January 26, 1843, and was educated at Cheltenham and Cambridge (Trinity College). He went into the family business of flax-spinning, the firm having been founded by his grandfather, who was among the first manufacturers to introduce flax-spinning on a large scale. He continued to be a member of the firm till it ceased to exist, after the death of his father in 1886. He then settled in the Lake Country, with which he had been familiar all his life, his grandfather, father, and uncles all having houses there. All these houses had rain-gauges, and interest had always been taken by their owners in rainfall statistics. When Mr. Stephen Marshall settled in the country he organised, in 1890, a network of rain-gauges approximately covering the district, which has remained in operation ever since.

He died in the South of France in February 1904, from pneumonia, after only five days' illness.

He was elected a Fellow of this Society on February 21, 1900.

FRANCIS NEWMAN, J.P., the County Surveyor for the Isle of Wight, died at Ryde, aged 73 years. Mr. Newman, who was a native of the Island, was elected surveyor to the Ryde Commissioners on January 13, 1857, and held office after the borough was incorporated until 1872. Then, owing to a municipal change of régime, he was out of office for a time, but was re-elected again in 1875, and continued to serve the town until 1897. Much of the efficiency of the Ryde water-supply and sewerage arrangements is due to his professional skill and thoroughness. His fame as a surveyor and engineer, and his knowledge of sanitary matters and of sea-defence work won him an extensive *clientèle*, and he was professionally connected with nearly all the island towns, as well as with Swanage and many places on the mainland. On the constitution of the island as an administrative county he was appointed county surveyor, which office he held at the time of his death. A few years ago his name was added to the Commission of the Peace for the borough, and he performed his magisterial duties with characteristic conscientiousness. In the year 1859 Mr. Newman was one of the promoters of the Volunteer movement in Ryde, and stood amongst the first of those sworn in as members of the local corps. When the various local corps were amalgamated he retained his connection with the island battalion, and retired with the rank of major, with permission to wear the uniform of his rank. He received a medal for long service and good conduct at the hands of the Duke of Connaught in the Portsmouth Town Hall. He

was also one of the founders of the Ryde School of Science and Art, and retained his connection with and interest in it until the very last.

He was elected a Fellow of this Society on February 19, 1879.

FRANK RUSSELL was born in Bristol and was educated at Ashley House School, Kingsdown. In 1886 he entered the service of the Royal Niger Company, and was for nearly thirty years in West Africa. While District Agent at Akassa he carried on meteorological and other scientific investigations, some of which he communicated to the Royal Meteorological Society. In 1901 Mr. Russell entered the Government Service, and was appointed Cantonment Magistrate at Zungeru, the new capital of Northern Nigeria. He died on August 6, 1904, of malaria at Streatham Hill, nine days after his arrival in England. He was in his 56th year.

He was elected a Fellow of this Society on June 17, 1891.

REV. MAURICE ALLEN SMELT was born in 1821. He went to Gonville and Caius College, Cambridge, and took his degree in 1842. He was ordained deacon in 1843, and after holding curacies in Kent and Hampshire was Rector of Medstead, Hants, from 1863 to 1867. He retired to Cheltenham, and gave ready assistance to religious and philanthropic societies. In particular he was for twenty years honorary secretary to the Cheltenham and Gloucester Society for the Blind. He took an interest in several branches of science, especially Astronomy and Meteorology, and was a Fellow of the Royal Astronomical Society.

Mr. Smelt died on December 6, 1904, at the age of 84 years.

He was elected a Fellow of this Society on November 27, 1855.

REV. FENWICK WILLIAM STOW, M.A., was born at Springfield Mount, Leeds, but his early years were spent at Red Hall, Roundhay, near Leeds. He was educated at Harrow, and was Lyon Scholar in 1859. In 1860 he entered Trinity College, Cambridge, when Dr. Whewell was Master, and became a Scholar of his College. He was tenth in the First Class of the Classical Tripos early in the year 1864, and took his M.A. in 1867.

After holding a Mastership at the Charterhouse, he was ordained Deacon, 1867, and Priest, 1868, by Archbishop Longley of Canterbury. He was Curate of Holy Trinity, Tunbridge Wells (under Canon Hoare), 1867-1869; of Hawsker, near Whitby, 1869-1871, and of Harpenden, Herts, 1871-1873. He was presented to the living of Aysgarth in 1873 by Trinity College, and held it for 31 years. He was elected a member of the Ripon Diocesan Conference in 1887, and made Rural Dean of Catterick West in 1895; was Surrogate for the Dioceses of Ripon and Wakefield, and for some years a Commissioner under the Pluralities Act. The parish of Aysgarth is an extensive one, and its proper management was no easy task. But in his earlier days he delighted in the long walks which his visits in the parish necessitated.

His sermons were remarkably thoughtful and suggestive, and by his hearty and genial manner and a genuine kindness of disposition he gained the affection of his parishioners of all classes. Mr. Stow was a man of wide and varied interests, a ripe classical scholar, a good amateur photographer, and an enthusiastic meteorologist. Some of his photos of the waterfalls in Wensleydale are to be seen in one of Miss Giberne's books.

Mr. Stow took great interest in meteorological observations and carried out numerous special experiments and investigations dealing with solar radiation, temperature in sun and shade, land and sea breezes, large and small anemometers, thermometer screens, Upbank thaws, etc. He communicated papers on these subjects to the Royal Meteorological Society.

He was elected a Fellow of this Society on March 21, 1866, and served on the Council 1872-1873. He died on July 24, 1904.

WILLIAM HENRY TYNDALL was born in the West Indies in 1813, and was a nephew of Charles Ansell, F.R.S. Mr. Tyndall succeeded Mr. Ansell as Actuary of the Atlas Assurance Company, and retired from that office many years before his death. He was twice married, and had six children, all of whom he survived.

He took great interest in geology and the microscope, and was a born naturalist. He contributed for many years his meteorological observations at Redhill to the Croydon Natural History Society. He was a generous supporter of religious and charitable societies.

He died on January 13, 1904, in the 91st year of his age.

He was elected a Fellow of this Society on February 15, 1882.

APPENDIX IV.

PURCHASES DURING THE YEAR 1904.

BOOKS.

ATKINS, J.—A Meteorological Journal for the year 1782, kept at Minehead in Somersetshire. *Phil. Trans.* 74, 1784.

BROOKE, R.—A Thermometrical Account of the Weather, for one Year, beginning September 1753, kept in Maryland. *Phil. Trans.* 51, 1759.

DAVY, J.—Notice of an unusual Fall of Rain in the Lake District, 1829.—On an unusual Drought in the Lake District, 1859. *Trans. R. Soc. Edin.* 22, 1861.

DYMOND, J., and WALES, W.—Observations on the State of the Air, Winds, Weather, etc., made at Prince of Wales's Fort on the North-west Coast of Hudson's Bay, in the Years 1768 and 1769. *Phil. Trans.* 60, 1770.

HELLMANN, G.—Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus. No. 15. Denkmäler Mittelalterlicher Meteorologie.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE. Second Annual Issue. F. Meteorology, including Terrestrial Magnetism.—Third Annual Issue. C. Physics. 8°. London, 1904.

NANSEN, F.—Farthest North. 8°. Westminster, 1897. 2 vols.

POGGENDORFF, J. C.—Biographisch-literarisches Handwörterbuch, Band IV. herausgegeben von Prof. Dr. A. J. von Oettingen. 8°. Leipzig, 1904.

READ, J.—A Meteorological Journal, principally relating to Atmospheric Electricity: kept at Knightsbridge, from the 9th of May 1789 to the 8th of May 1790. *Phil. Trans.* 81, 1791.

READ, J.—A Meteorological Journal, principally relating to Atmospheric Electricity: kept at Knightsbridge, from the 9th of May 1790 to the 8th of May 1791. *Phil. Trans.* 82, 1792.

REPORT ON THE METEOROLOGY OF THE PUNJAB, 1868, 1871, 1872. Fcp. Lahore.

YEAR-BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES OF GREAT BRITAIN AND IRELAND, 1903-1904. London, 1904.

LANTERN SLIDES.

Fog Billows (10 slides).

APPENDIX V.

DONATIONS RECEIVED DURING THE YEAR 1904.

Books and Pamphlets.

Presented by Societies, Institutions, etc.

Aachen, Meteorologische Observatorium.—Ergebnisse der Beobachtungen am Observatorium und dessen Nebenstationen, 1903.

Adelaide, Observatory.—Meteorological Observations made at Adelaide Observatory and other places in South Australia and the Northern Territory, 1900-1901.

Bangalore, Central Observatory.—Meteorology in Mysore, 1903.—Report on the Rainfall Registration in Mysore, 1903.

Barbados, Colonial Secretary's Office.—Returns of Rainfall in Barbados, 1904.

Barcelona, Observatorio Belloch-Llinas.—Hojas meteorologicas, 1903.

Batavia, Magnetical and Meteorological Observatory.—Observations, vol. xxv. 1902.—Rainfall in the East Indian Archipelago, 1902.

Berlin, Deutsche meteorologische Gesellschaft.—Meteorologische Zeitschrift, Dec. 1903 to Nov. 1904.

Berlin, Gesellschaft für Erdkunde.—Zeitschrift, 1903, No. 10 to 1904, No. 5.

Berlin, Königlich-Preussisches meteorologisches Institut.—Abhandlungen, Band II. parts 3-4.—Archiv des Erdmagnetismus, Heft 1.—Bericht über die Thätigkeit des Königlich-Preussischen meteorologischen Instituts im Jahre 1903.—Deutsches Meteorologisches Jahrbuch, 1903. Preussen und benachbarte Staaten.—Ergebnisse der Arbeiten am Aëronautischen Observatorium 1 Oktober 1901, bis 31 December 1902.—Ergebnisse der Beobachtungen an den Stationen II. und III. Ordnung, 1890, Heft 1; 1892, Heft 3; 1896, Heft 1 ; 1899, Heft 1.—Ergebnisse der Meteorologischen Beobachtungen in Potsdam, 1901.—Ergebnisse der Wolkenbeobachtungen in Potsdam 1896 und 1897.

Bidston, Liverpool Observatory.—Report of the Director, 1903.

Birmingham and Midland Institute.—Records of Meteorological Observations taken at the Observatory, Edgbaston, 1903.

Bognor, Climatological Society.—Report, 1903.

Bombay, Government Observatory.—Magnetical, Meteorological, and Seismological Observations, 1900-1.

Bremen, Meteorologische Station.—Deutsches Meteorologisches Jahrbuch für 1892 and 1903. Freie Hansestadt Bremen.

Brisbane, General Register Office.—Annual Report on the Vital Statistics of Queensland, 1903.

Brisbane, Queensland Geographical Society. — Queensland Geographical Journal, 1902-3.

British New Guinea, Government Secretary's Office.—Annual Report for the Year ending June 30, 1903.

Brussels, Académie Royale de Belgique.—Annuaire, 1904.—Bulletin de la classe des Sciences, 1903, No. 11 to 1904, No. 11.

Brussels, Observatoire Royale de Belgique.—Annuaire Astronomique, 1901-5.—Annuaire météorologique, 1904.

Bucharest, Institut Météorologique de Roumanie.—Buletinul lunar al observatiunilor meteorologice, 1903.—Climatologia Bucuresciana, 1900-1.—Starea udometrica si agricolă a Romaniei.

Cairo, Société Khédiviale de Géographie.—Bulletin, VIme série, Nos. 3-5.

Cairo, Survey Department, Public Works Department.—Meteorological Observations made at Abbassia, Alexandria, Assiut, Aswan, Berber, Duem, Giza, Khartum, Port Said, Suakin, Wadi Halfa, and Wadi Medani, Nov. 1903 to June 1904.—Meteorological Report, 1901.—On the Variations of Level of Lake Victoria, by Capt. H. G. Lyons.

Calcutta, Meteorological Department of the Government of India.—Indian Daily Weather Reports, Dec. 1, 1903, to Nov. 30, 1904.—Indian Meteorological Memoirs, vol. xv. part iii. and vol. xvii.—Monthly Weather Review, July 1903 to June 1904.—Rainfall of India, 1903.—Report on the Administration of the Meteorological Department, 1903-4.

Cambridge, Mass., Blue Hill Meteorological Observatory.—Observations and Investigations, 1901 and 1902.

Cape Town, South African Association for the Advancement of Science.—Report, 1903.

CAPE TOWN, METEOROLOGICAL COMMISSION.—Report, 1902.

CAPE TOWN, SOUTH AFRICAN PHILOSOPHICAL SOCIETY.—Transactions, vol. xiii. part i., vol. xiv. parts iii.-v., and vol. xv. parts i.-ii.

CARDIFF, ASTRONOMICAL SOCIETY OF WALES.—The Cambrian Natural Observer, 1902.

CARLSRUHE, CENTRALBUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE IM GROSSHERZOGTHUM BADEN.—Jahrbuch, 1903.—Niederschlags-beobachtungen der meteorologischen Stationen im Grossherzogthum Baden, 1903, part ii., and 1904, part i.

CHEMNITZ, KÖNIGL.-SÄCHSISCHES METEOROLOGISCHES INSTITUT.—Jahrbuch, 1900.

CHRISTIANIA, NORSKE METEOROLOGISKE INSTITUT.—Jahrbuch, 1903.—Oversigt over Luftens Temperatur og Nedboren i Norge i Aaret, 1902.—Nedbor Iagttagelser i Norge, 1903.

COPENHAGEN, COMMISSION DANOISE DES EXPLORATIONS GÉOGRAPHIQUES ET GÉOLOGIQUES DU GRŒNLAND.—Observations astronomiques, météorologiques, et magnétiques de Tasuisak dans le district d'Angmagsalik, 1898-99, par G. C. Amdrup.

COPENHAGEN, DANSKE METEOROLOGISKE INSTITUT.—Bulletin météorologique du Nord, Dec. 1903 to Nov. 1904.—Meteorologisk Aarbog, 1902, part ii.; 1903, part i.—Nautisk-Meteorologisk Aarbog, 1903.—Observations de la direction des nuages faites en Danemark, aux Faeröe, en Islande, et au Grœnland, 1896-97.

CORDOBA, ACADEMIA NACIONAL DE CIENCIAS.—Boletin, tomo xvii. part ii.

CORDOBA, OFICINA METEOROLOGICA ARGENTINA.—Carta del Tiempo, Dec. 1903 to Oct. 1904.

CORNWALL COUNTY COUNCIL, SANITARY COMMITTEE.—Monthly Report, Dec. 1903 to Nov. 1904.

COSTA RICA, INSTITUTO FISICO GEOGRAFICO.—Boletin, Nos. 29-36.

CRACOW, K. K. STERNWARTE.—Meteorologische Beobachtungen, Aug. 1903 to Jan. 1904.

CROYDON, NATURAL HISTORY AND SCIENTIFIC SOCIETY.—Daily Rainfall in the Croydon District, Dec. 1903 to Oct. 1904.—Report of the Meteorological Sub-Committee, 1903.

DAVOS PLATZ, KURVEREINE.—Davoser Wetterkarte, Nov. 1903 to Oct. 1904.

DUBLIN, GENERAL REGISTER OFFICE.—Weekly Returns of Births and Deaths, 1904.

DUBLIN, ROYAL IRISH ACADEMY.—Proceedings, vol. xxiv. section A, part iii. to vol. xxv. part ii.—Transactions, vol. xxxii. section A, Nos. 7-10.

EDINBURGH, GENERAL REGISTER OFFICE.—Quarterly Returns of the Births, Marriages, and Deaths registered in Scotland, for the year ending Sept. 30, 1904.

EDINBURGH, ROYAL SCOTTISH GEOGRAPHICAL SOCIETY.—Scottish Geographical Magazine, 1904.

FIUME I. R., ACCADEMIA DI MARINA.—Meteorological Observations, Aug. 1903 to Jan. 1904.

GENEVA, SOCIÉTÉ DE GÉOGRAPHIE.—Le Globe, tome xliii.

GLASGOW, ROYAL PHILOSOPHICAL SOCIETY.—Proceedings, 1903-04.

GREENWICH, ROYAL OBSERVATORY.—Magnetical and Meteorological Observations, 1901.—Report of the Astronomer-Royal to the Board of Visitors, June 4, 1904.

HAMBURG, DEUTSCHE SEEWARTE.—Annalen der Hydrographie und Maritimen Meteorologie, 1904.—Aus dem Archiv, 1903.—Deutsche Ueberseeische meteorologische Beobachtungen, Heft 12.—Ergebnisse der meteorologischen Beobachtungen, 1902.—Ergebnisse der Meteorologischen Beobachtungen im System der Deutschen Seewarte fur das Lustrum 1896-1900, sowie fur die 25 Jahre 1876-1900.—Erklarüng der von Deutschen Seewarte in den Witterungsberichten und Wettervorhersagen angewandten Ausdrücke.—Jahresbericht, 1903-4.—Wetterbericht, 1904.—Nachtrag zum Katalog v.

HONG-KONG, OBSERVATORY.—China Coast Meteorological Register, 1903.—Extract of Meteorological Observations, Nov. 1903 to Oct. 1904.

JAMAICA, GOVERNMENT METEOROLOGIST.—Weather Report, Oct. 1903 to Sept. 1904.

JERSEY, OBSERVATOIRE ST. LOUIS.—Bulletin des Observations magnétiques et météorologiques, 1903.

JURJEW, METEOROLOGISCHE OBSERVATORIUM.—Meteorologische Beobachtungen, angestellt in Jurjew im Jahre 1903.—Bericht über die Ergebnisse der Beobachtungen für das Liv-Estländische Regenstationsnetz, 15 jährige Mittelwerte, 1886-1900.

KAZAN, OBSERVATOIRE MÉTÉOROLOGIQUE.—Bulletin, June 1902 to Feb. 1903.

KINGSTON, INSTITUTE OF JAMAICA.—The Meteorology of Jamaica, by M. Hall.

LEON, OBSERVATORIO METEOROLÓGICO.—Boletin Mensual, Nov. 1903 to Oct. 1904.

LISBON, OBSERVATORIO DO INFANTE D. LUIZ.—Annaes, 1901.—Boletim Meteorologico, 1904.

LISBON, SOCIEDADE DE GEOGRAPHIA.—Boletim, 21a serie, No. 8; 22a serie, No. 10.

LONDON, AERONAUTICAL SOCIETY.—Aeronautical Journal, 1904.

LONDON, BRITISH ASSOCIATION.—Report, 1903.

London, British Balneological and Climatological Society.—The Journal of Balneology and Climatology, vol. viii.

London, General Register Office.—Quarterly Returns of Marriages, Births, and Deaths for the year ending Sept. 30, 1904.—Weekly Returns of Births and Deaths, 1904.

London, Geological Society.—Quarterly Journal, 1904.

London, Institution of Civil Engineers.—Mean and Extreme Annual Rainfall over the British Isles, by Dr. H. R. Mill.

London, Institution of Electrical Engineers.—Journal, Nos. 164 to 169.

London, Junior Institution of Engineers.—Record of Transactions, 1902-3.

London, Meteorological Office.—Daily Weather Report, 1904.—Weekly Weather Report, 1904.—Climatological Observations at Colonial and Foreign Stations: I. Tropical Africa, 1900-2.—Hints to Meteorological Observers in Tropical Africa.—Hourly Readings at the four Observatories under the Meteorological Council, 1900.—Monthly Wind Charts of the South Atlantic Ocean.—Report of the International Meteorological Committee, Southport, 1903.—Monthly Pilot Chart of the North Atlantic and Mediterranean, Feb. 1904 to Jan. 1905.—Report of the Meteorological Council for the year ending March 31, 1903.—Bulletin quotidien de l'Algérie, Oct. 1903-Nov. 1904 incomplete.—Ceylon Administration Reports, 1903: II. Meteorology.—London Fog Inquiry, 1901-3.

London, National Physical Laboratory.—Report, 1903.

London, Physical Society.—Proceedings, Nos. 110 to 113.

London, Royal Agricultural Society.—Journal, 1903.

London, Royal Astronomical Society.—Monthly Notices, 1904.

London, Royal Botanic Society.—Quarterly Record, Jan. to June and Oct. 1903 to June 1904.

London, Royal Geographical Society.—Geographical Journal, 1904.—On Recent Contributions to our Knowledge of the Floor of the North Atlantic Ocean.

London, Royal Society.—Proceedings, Nos. 487 to 502.—Magnetic and Meteorological Observations made by the "Southern Cross" Antarctic Expedition, 1898-1900.—The Atoll of Funafute.—Year Book, 1904.

London, Royal Statistical Society.—Quarterly Journal, Dec. 1903 to Sept. 1904.

London, Royal Sanitary Institute.—Journal, vol. xxiv. No. 4 to vol. xxv. No. 2.

London, Society of Accountants and Auditors.—The Incorporated Accountants' Year Book, 1903-4.

London, Society of Arts.—Journal, 1904.

London, Solar Physics Observatory.—International Meteorological Committee. Commission for the Combination and Discussion of Meteorological Observations from the point of view of their Relations with Solar Phenomena.—Report of Preliminary Proceedings, by W. N. Shaw.—Report of Proceedings of the First Meeting, Cambridge, August 18-23, 1904.

London, Underground Water Preservation Association.—Measurements of Well-levels and Rainfall as recorded on Association's Chart.

Madrid, Instituto Central Meteorológico.—Boletin, 1904.

Madrid, Sociedad Geographica.—Boletin, tomo xlv. No. 3 to tomo xlvi. No. 2.—Revista de geografia colonial y mercantil publicada por la sección de geografia comercial, Actas de las sesiones celebradas por la sociedad por la junta directiva y por las secciones, tomo ii. Nos. 24 to 32.

Manchester, Literary and Philosophical Society.—Memoirs and Proceedings, vol. xlviii. parts i. to iii.

Manila, Philippine Weather Bureau.—Climate of the Philippines, by the Rev. J. Algué.—Philippine Weather Review, July 1903 to June 1904.—Report of the Director, 1902, parts iv. and v.—The Cyclones of the Far East, by Rev. J. Algué.—Volcanoes and Seismic Centres of the Philippine Archipelago, by the Rev. M. S. Maso.

Marlborough College, Natural History Society.—Report, 1903.

Marseilles, Commission de Météorologie du Département des Bouches-du-Rhône.—Bulletin Annuel, 1903.

Mauritius, Royal Alfred Observatory.—Annual Report of the Director, 1903.—Results of Magnetical and Meteorological Observations, 1900-1.

Merzifun (Asia Minor), Anatolia College.—Meteorological Records, 1903.

Mexico, Observatorio Astronomico Nacional.—Informes presentados à la Secretaria de Fomento sobre los trabajos del establecimiento.

Mexico, Observatorio Meteorológico-Magnético Central.—Boletin Mensual, March to July 1902.

Mexico, Sociedad Cientifica "Antonio Alzate."—Memorias y Revista, tomo xiii. Nos. 7-8; tomo xviii. No. 6; tomo xix. Nos. 5, 8-10; tomo xx. Nos. 1-4, 5-10.

Michigan, State Board of Health.—Annual Report, 1902.—Principal Meteorological Conditions in Michigan, 1902.

MILAN, R. OSSERVATORIO ASTRONOMICO DI BRERA.—Osservazioni meteorologiche, 1903.—Pubblicazioni, No. 40, parte i., No. 42.

MONTEVIDEO, OBSERVATORIO METEOROLÓGICO DEL COLEGIO PÍO DE VILLA COLÓN.—Boletin Mensual, March to Nov. 1903.

MOSCOW, SOCIÉTÉ IMPÉRIALE DES NATURALISTES.—Bulletin, 1902, Nos. 3-4 ; 1903, Nos. 2-4 ; 1904, No. 1.

NEW YORK, ACADEMY OF SCIENCES.—Annals, vol. xiv. parts 3-4.

NEW YORK, CENTRAL PARK OBSERVATORY.—Abstracts of Registers from Self-recording Instruments, Dec. 1903 to Oct. 1904.

ODESSA, OBSERVATOIRE MAGNÉTIQUE ET MÉTÉOROLOGIQUE.—Annales, 1901-3.

O-GYALLA, CENTRAL OBSERVATORIUM.—Beobachtungen, Nov. 1903 to Oct. 1904.—Bibliothek. Liste des Zuwachs, 1903.

OÑA (SPAIN), COLEGIO MAXIMO DE LA COMPAÑIA DE JESUS.—Observaciones Meteorológicas, 1903.

ORTHEZ, ASSOCIATION MÉTÉOROLOGIQUE ET CLIMATOLOGIQUE DU SUD-OUEST DE LA FRANCE.—Bulletin Mensuel de l'Observatoire Carlier d'Orthez, July to Sept. 1903 and Feb. to July 1904.

OTTAWA, DEPARTMENT OF MARINE AND FISHERIES.—Report of the Meteorological Service of Canada, 1902.

OTTAWA, GEOLOGICAL SURVEY OF CANADA.—Altitudes in the Dominion of Canada.—Annual Report, 1900.—Catalogue of Canadian Birds, part iii.

PARIS, BUREAU CENTRAL MÉTÉOROLOGIQUE DE FRANCE.—Annales, 1900-1.—Bulletin International, 1904.—Bulletin Mensuel, Oct. 1903 to Oct. 1904.—Rapport du Comité Météorologique International Réunion de Southport, 1903.

PARIS, OBSERVATOIRE MUNICIPAL (OBSERVATOIRE DE MONTSOURIS).—Annales, 1900.

PARIS, SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE.—Annuaire, Dec. 1903 to Nov. 1904.

PERPIGNAN, OBSERVATOIRE.—Bulletin météorologique du Départment des Pyrénées-Orientales, 1891-2, 1902.

PERTH (WESTERN AUSTRALIA), OBSERVATORY.—Meteorological Observations made at the Perth Observatory and other places in Western Australia during the year 1902.

PHILADELPHIA, AMERICAN PHILOSOPHICAL SOCIETY.—Proceedings, Nos. 174 to 177.

POLA, K.-K. HYDROGRAPHISCHES AMT.—Meteorologische Termin-Beobachtungen in Pola und Sebenico, Nov. 1903 to Oct. 1904.—Jahrbuch der meteorologischen erdmagnetischen und seismischen Beobachtungen, 1903.—Veröffenlichungen des Hydrographischen Amtes ; Gruppe 1. Nachtliche Kimmtiefen-Beobachtungen zu Verudella. Ausgefuhrt, 1902-3.

POLA, K.-K. HYDROGRAPHISCHEN CENTRAL-BUREAUS.—Jahrbuch, 1901.

PRAGUE, K.-K. STERNWARTE.—Magnetische und meteorologische Beobachtungen, 1903.

PRETORIA, TRANSVAAL METEOROLOGICAL DEPARTMENT.—Administration Report, 1903-4.

REGINA, DEPARTMENT OF AGRICULTURE OF THE NORTH-WEST TERRITORIES.—Annual Report, 1903.

RIO DE JANEIRO, MINISTERIO DA MARINHA.—Boletim des observaçoes meteorologicas, Apr. 1903 to Mar. 1904.—Boletim Semestral, Nos. 11 and 12.

RIO DE JANEIRO, OBSERVATORIO.—Annuario, 1904.—Boletim Mensal, Apr. to Dec. 1903.

ROME, SOCIETÀ SISMOLOGICA ITALIANO.—Bollettino, vol. ix. No. 5 to vol. x. No. 2.

ROME, UFFICIO CENTRALE DI METEOROLOGICA E DI GEODINAMICA.—Revista Meteorico-Agraria, Anno xxiv. No. 33 to Anno xxv. No. 26.

ROTHAMSTED, LAWES AGRICULTURAL TRUST.—Plans and Summary Tables arranged for reference in the Fields, 1904.

ST. PETERSBURG, CENTRAL PHYSICAL OBSERVATORY.—Annales, 1901.—Report of the Nicolas Central Physical Observatory, 1901, by M. Rikatcheff [in Russian].

SAN FERNANDO, INSTITUTO Y OBSERVATORIO DI MARINA.—Annales, 1902-3.

SÃO PAULO, COMMISSÃO GEOGRAPHICA E GEOLOGICA DE SÃO PAULO.—Dados climatologico, 1902.

SOUTHPORT, FERNLEY OBSERVATORY.—Report and Results of Observations, 1903.

STOCKHOLM, METEOROLOGISKA CENTRAL-ANSTALTEN.—Månadsöfversigt af Väderleken i Sverige, Nov. 1903 to Nov. 1904.—Meteorologiska Iakttagelser i Sverige, 1901-3.

STONYHURST, COLLEGE OBSERVATORY.—Results of Meteorological and Magnetical Observations, 1903.

STRASSBURG, INTERNATIONALE KOMMISSION FÜR WISSENSCHAFTLICHE LUFTSCHIFFAHRT.—Beobachtungen mit bemannten, unbemannten Ballons und Drachen sowie auf Berg- und Wolken-stationen, 1901, 1902, and Jan.-Aug. 1903.

SYDNEY, OBSERVATORY.—Results of Meteorological Observations in New South

Wales, 1900.—Results of Rain, River, and Evaporation Observations in New South Wales, 1900.—Weather Charts, 1902.

TACUBAYA, OBSERVATORIO ASTRONÓMICO NACIONAL.—Anuario, 1904.

TOKIO, CENTRAL METEOROLOGICAL OBSERVATORY.—Annual Report, 1896, part 2; 1899, part 2; and 1900, part 1.—Bulletin, No. 1.—The Organisation of the Meteorological Service of Japan.

TOKIO, IMPERIAL UNIVERSITY.—Calender, 1903-4.

TOKIO, METEOROLOGICAL SOCIETY OF JAPAN.—Journal, Nov. 1903 to Sept. 1904.

TORONTO, METEOROLOGICAL OFFICE.—Monthly Weather Review, Oct. 1903 to Aug. 1904.—Toronto General Meteorological Register, 1903.

TRIESTE, I. R. OSSERVATORIO ASTRONOMICO METEOROLOGICO.—Rapporto Annuale, 1901.

UPSALA, OBSERVATOIRE MÉTÉOROLOGIQUE DE L'UNIVERSITÉ.—Bulletin Mensuel, 1903.—Expedition de M. A. G. Nathorsten, 1899. Recherches oceanographiques par F. Åkerblom.

UTRECHT, K.-NEDERLANDSCH METEOROLOGISCHE INSTITUT.—Analyse des mouvements périodiqnes et apériodiques du niveau de la mer.—Maandelysch Overzicht der weersgesteldheid in Nederland.—Meteorologisch Jaarboek, 1902.—Onweders in Nederland, 1902.

VALPARAISO, SERVICO METEOROLOGICO REPUBLICA DE CHILE.—Anuario, 1899-1901.

VICTORIA, DEPARTMENT OF AGRICULTURE.—Journal, 1904.

VIENNA, HOHE WARTE.—Jahres-Bericht des Sonnblick Vereins, 1903.

VIENNA, K.-K. CENTRALANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Beobachtungen, July to Dec. 1903.—Jahrbuch, 1902.—Klimatographie von Österreich, 1. Klimatographie von Niederösterreich.

VIENNA, K.-K. HYDROGRAPHISCHEN CENTRAL BUREAUS.—Jahrbuch, 1902.

VIENNA, LANDESSTATIONEN IN BOSNIEN-HERCEGOVNIA.—Ergebnisse der Meteorologischen Beobachtungen im Jahre 1900.

VIENNA, OESTERREICHISCHE GESELLSCHAFT FÜR METEOROLOGIE.—Meteorologische Zeitschrift, Dec. 1903 to Nov. 1904.

WARSAW, BUREAU MÉTÉOROLOGIQUE.—Wplyn zmiennej dzialalnósci slönca na nieokresowe ruchy atmosfery ziemskiej, by R. Merecki.

WASHINGTON, HYDROGRAPHIC OFFICE.—Pilot Chart of the North Atlantic Ocean, 1904.—Pilot Chart of the North Pacific Ocean, 1904.—West India Hurricanes.

WASHINGTON, SMITHSONIAN INSTITUTION.—Excerpt papers from the Smithsonian Report, Nos. 1383, 1385-1390.

WASHINGTON, UNITED STATES GEOLOGICAL SURVEY.—Water-supply and Irrigation papers, Nos. 80-87.—Professional papers, Nos. 9, 10, 13-15.

WASHINGTON, UNITED STATES NAVAL OBSERVATORY.—Meteorological Observations and Results, 1893-1902.

WASHINGTON, WEATHER BUREAU.—Maryland and Delaware Section of the Climate and Crop Service of the Weather Bureau, Nov. 1903 to Sept. 1904.—Monthly Weather Review, Oct. 1903 to Sept. 1904.—Report of the Chief, 1902-3.—Climatology of California, by A. G. M'Adie.—Studies among the Snow Crystals during the Winter of 1901-2, by W. A. Bentley.—The Floods of the Spring of 1903 in the Mississippi Watershed, by H. C. Frankenfeld.—Weather Folk Lore and Local Weather Signs, by E. B. Garriot.

WATFORD, HERTFORDSHIRE NATURAL HISTORY SOCIETY.—Transactions, vol. xii. parts 1 and 2.

WELLINGTON COLLEGE, NATURAL SCIENCE SOCIETY.—Report, 1903.

WELLINGTON (N.Z.), GENERAL REGISTER OFFICE.—New Zealand Official Year Book, 1903.—Statistics of the Colony of New Zealand, 1902.

WESTERN AUSTRALIA, AGENT-GENERAL.—Climate and Rainfall of Western Australia, Nov. 1903 to Oct. 1904.

YOURIEF (LIVONIA) STATION MÉTÉOROLOGIQUE DE L'ECOLE REALE.—Observations, Jan. to Sept. 1903.

ZI-KA-WEI (SHANGHAI), OBSERVATOIRE MAGNÉTIQUE ET MÉTÉOROLOGIQUE.—Bulletin des Observations, 1901.

ZOMBA, SCIENTIFIC DEPARTMENT.—Meteorological Observations, Oct. 1903 to Aug. 1904.—Result of Nyassaland Meteorological Observations, 1903.

ZURICH, SCHWEIZERISCHEN METEOROLOGISCHEN CENTRAL-ANSTALT.—Annalen, 1902.

Presented by Individuals.

ARCTOWSKI, H.—Antarctic Meteorology and International Co-operation in Polar Work.—Aperçu des résultats météorologiques de l'hivernage Antarctique de la *Belgica*.

ASSMANN, R.—The Temperature of the Air above Berlin, Oct. 1, 1902, to Dec. 31, 1903.

BADGLEY, (Col.) W. F.—Comets' Tails.
BARBER, Miss.—The Cloud World, by (Rev.) S. Barber.
BARKER, C. J.—Meteorological Observations at Sheffield, Dec. 1903 to Mar. 1904.
BAXENDELL, J.—Meteorological Observations at Southport, Dec. 1903 to Nov. 1904.
BEADLE, C.—Chapters on Papermaking.
BENN, C. H.—Penzance Meteorological Reports, 1898-1903.
BIGGS, J. W. H.—Sunshine in the English Lake District, 1903, Comparative Table.
BLACK, W. G.—Ocean Rainfalls.
BLADEN, W. W.—Annual Report North Staffordshire Field Club, 1903-4.
BROWN, A., and BOOBBYER, (Dr.) P.—The Meteorology of Nottingham, 1903.
CHREE, (Dr.) C.—An Analysis of the Results from the Kew Magnetographs on "Quiet Days" during 1890 to 1900.—An Enquiry into the Nature of the Relationship between Sun-spot Frequency and Terrestrial Magnetism.
CLARK, J. E.—A Year of Rain.—Lake Pickering.—The Great Storm in Croydon, Saturday, May 30, 1903.—The Geology of Somerset's Submerged Tenth.—The Mystery of Mammoth.—The Nine Weeks' Frost.—Twenty Years of Migrant Records.
CLEMENTS, H.—New Method of World Weather Forecasting. Predictions for March to June, 1904.—Weather Predictions for the Autumn, 1904.
COLBORNE, H.—Annual Report, Meteorological Observations, Borough of Hastings, 1903.
COOKE, R.—Register of Rainfall kept at Detling near Maidstone, 1903 [M.S.].
CORBETT, (Dr.) D.—Report on the Health of the Borough of Kidderminster, 1903.
COUTTS, (Dr.) F. J. H.—Annual Report, Medical Officer of Health, Blackpool, 1903.
DEMTCHINSKY, N.—Climat, vol. vi., parts 3 and 4.
DIXON, C.—Results of Meteorological Observations taken at Holland House, Middlesex, Dec. 1903 to Nov. 1904 (MS.).
DOVER, J.—Totland Bay, I.W. Report of Meteorological Observations, 1901-3.
DOYLE, P.—Indian Engineering, 1904.
EATON, H. S.—Returns of Rainfall, etc., in Dorset, 1903.
EDITOR.—Ciel et Terre, 1904.
EDITOR.—Daily Graphic, 1904.
EDITOR.—Electrical Review, 1904.
EDITOR.—Nature, 1904.
EDITOR.—Observatory, 1904.
EDITOR.—Science Abstracts, vol. vii., parts 1-5.
EDWARDS, C. W.—Meteorology of Lowestoft, 1903.
ELLIS, W.—The Aurora and Magnetic Disturbance.—Obituary Notice of James Glaisher.
ENGELMANN, W.—Jelinek's Psychrometer-Tafeln erweitert und vermehrt von J. Hann, neu herausgegeben und mit Hygrometer-Tafeln versehen, von J. M. Pernter.
EXNER, F. M.—Ueber eine Beziehung zwischen Luftdruckverteilung und Bewolkung.
FASSIG, (Dr.) O. L.—Kite Flying in the Tropics.—Outline of a Report upon the Weather and Climate of Baltimore and vicinity.
FIGEE, S.—Perioden in den Regenval op Java.
FOX, W. L. — Meteorological and Magnetical Tables and Reports, Falmouth Observatory, 1903.
GAUTIER, R.—Observations météorologiques faites aux fortifications de St. Maurice, 1902.—Résumé météorologique pour Genève et le Grand St. Bernard, 1902.
GORCZYNSKI, L.—Études sur la marche annuelle de l'insolation.
GRENANDER, S.—Les variations annuelles de la température dans les lacs suèdois.
GUNN, (Dr.) J. ST. C.—Abstract of Climatological Observations made at Kaikoura, New Zealand, 1903 (MS.).
HALL, M.—The Meteorology of Jamaica.
HAMBERG, H. E.—La pression atmosphérique moyenne en Suède, 1860-95.—Der Sommernachtfröste in Schweden, 1871-1900.
HANDS, A.—Necessary Practical Safeguards against Lightning.—Scientific Protection: A Guide to the proper application of Lightning Conductors.—Thunderstorms: the Damage they cause and the means of Protection.
HANN, (Dr.) J.—Die Anomalien der Witterung auf Island in dem Zeitraume, 1851 bis 1900, und deren Beziehungen zu den gleichzeitigen Witterungsanomalien in Nordwesteuropa.—Ueber die Temperaturabnahme mit der Höhe bis zu 10 km nach den Ergebnissen der internationalen Ballonaufstiege.
HARVEY, (Rev.) C. W.—Meteorological Observations, Throcking Rectory, 1903.
HEIMROD, G.—Results of Harmonic Analysis of the Diurnal Variation at the Cape of Good Hope and at Hobart.
HERGESELL, (Dr.) H.—Rapport sur les Travaux de la Commission Internationale pour l'aérostation scientifique.
HEYWOOD, H.—Meteorological Observations in the [Cardiff] Society's District, 1903.

HILL, G. H., & Sons.—Returns of the Rainfalls in the Glasgow, Manchester, Ashton, Dewsbury, Stockport, Halifax, Blackburn, Holme Reservoirs, Oldham, and Batley Waterworks Districts, 1903.

HOOREMAN, F.—Le vent dans l'antiquité.—Les enregistreurs électriques d'orages.

HORNER, D. W.—Fireside Astronomy.

HUNTER, J.—Meteorological Observations at Belper, 1904.

KELLY, (the late) Dr. C.—Weather Report, Worthing, Nov. 1903 to Feb. 1904.

KEYS, R. P.—Dover: A Reminiscence of its History, Past and Present.

KÖRÖSY (Dr.) J. v.—Die Hauptstadt Budapest im Jahre 1901.

KREMSER, V.—Bericht über die zehnte Allgemeine Versammlung der Deutschen Meteorologischen Gesellschaft zu Berlin 7-9 Apr. 1904.

LAMB, E.—Climatological Observations taken at Borden Wood, 1903.

LATHAM, B.—Croydon Bourne Flows.

LELIAN, (Capt.) P. S.—MS. Meteorological Observations made during May to September in the Sokoto Arc, Northern Nigeria.

LOCKYER, Sir N., and LOCKYER, W. J. S.—The Behaviour of the Short Period Atmospheric Pressure Variation over the Earth's Surface.

MACMILLAN & Co.—Weather Influences, by E. G. Dexter.

MARCH, F.—Borough of Torquay, Meteorological Reports, 1900-3.

MARKHAM, C. A.—Meteorological Report for Northamptonshire, Oct. 1903 to Sept. 1904.

MARRIOTT, W.—Lambrecht's Polymeter.

MARSHALL, (Dr.) A.—Borough and Port of Lowestoft, Annual Reports of the Medical Officer of Health, 1903.

MARSHALL, Miss.—Rainfall in the Lake District, Dec. 1903 to Nov. 1904.

MAWLEY, E.—Meteorological Observations at Rosebank, Berkhamsted, Nov. 5, 1903 to Dec. 7, 1904.—National Rose Society, Annual Report, 1904.

MEINARDUS, W.—Ueber Schwankungen der Nordatlantischen Zirkulation und ihre Folgen.

MELLISH, H.—The Weather of 1903 at Hodsock Priory, Worksop.

MIDGLEY, W. W.—Annual Report of the Museums and Meteorological Observatory, Bolton, 1903.

MILL, (Dr.) H. R.—British Rainfall, 1903.—On Mean and Extreme Annual Rainfall in the British Islands.—Pocket Rain Register.—Rules for Rainfall Observers.—Symons' Meteorological Magazine, 1904.

MITCHELL, Rev. J. C.—Results of Meteorological Observations taken in Chester during 1903.

MOORE, (Sir) J. W.—Abstract of Meteorological Observations taken at Dublin during 1903.—Rainfall in 1903 at West Dublin.

MORGAN, E. R.—Swansea Rural District Council, Annual Reports of the Medical Officers of Health, 1903.

MORRIS, (Dr.) H. C. L.—Bognor as a Health Resort.

NASH, W. C.—Greenwich Rainfall, 1841-1902.—Rainfall and Sunshine in 1903.

PAGE, J.—Instructions to the Voluntary Meteorological Observers of the U.S. Hydrographic Office.

PARNABY, J. M.—Meteorological Report for Albert Park, Middlesborough, Dec. 1903 to Nov. 1904 [MS.].

PEEK, The Hon. Lady.—Meteorological Observations at Rousdon Observatory, Devon, 1903.

POYNTING, J. H.—Radiation in the Solar System: Its Effect on Temperature and its Pressure on Small Bodies.

PRESTON, A. W.—Meteorological Notes from Observations taken at Bradestone House, Brundall, Norwich, 1903.

RAULIN, V.—Sur la distribution des pluies en Australie pendant la period 1871-1880.

ROBINSON, T.—Report and Results of Observations, 1903, Hoylake.

ROTCH, A. L.—Atmospheric Electricity and Terrestrial Magnetism at the British Association for the Advancement of Science, 1903.—Meteorological Observations with Kites at Sea.—Meteorology at the British Association.

RUBENSON, (Dr.) R.—Etudes sur diverses méthodes servant à calculer la moyenne diurne de la température.

SALLE, O.—Das Wetter, 1904.

SAXBY, A. C.—Annual Report on the Meteorology of Cheltenham, 1903.—Meteorological Report, 1904.

SAXBY, (Dr.) T. E.—On the Occurrence of the Hawfinch and other Birds in Unst, Shetland.

SCHLICK, (Dr.) W.—Manual of Forestry, vol. 2.

SHEWARD, R.—Annual Report of the Meteorological Observations, Eastbourne, 1903.

SLADE, F.—Meteorological Observations for 1903 at Beckford.—The Rainfall at Beckford for the twenty years 1884 to 1903.

SMITH, J.—Something about the Weather in and around Banchory.

SNELL, E. H.—City of Coventry, Annual Report on the Health of the City, 1903.

STEEN, A. S.—Jordmagnetiske maalinger i Norge sommeren, 1902.—The Diurnal Variation of Terrestrial Magnetism.

STEWART, C. M.—Meteorology in South Africa.—A Note on the Quantities given in Dr. Marloth's Paper "On the Moisture deposited from the South-east Clouds."

STIATTESI, R.—Spoglio delle Osservazioni Sismiche dal 1 Agosto 1902 al 30 Novembre 1903.

STOKES, J.—Borough of Margate. Annual Report of the Medical Officer of Health for 1903, to which is appended the Meteorological Report.

STRACHAN, R.—Horological Journal, July and Sept., 1904.

SUTTON, J. R.—An Introduction to the Study of South African Rainfall.—The Determination of Mean Results from Observations made at Second-Order Stations on the Tableland of South Africa.

SYMONS, (Dr.) W. H.—Annual Report to the Bath Urban Sanitary Authority by the Medical Officer of Health, 1903.

THOMAS, J. LYNN.—Two Cases of Lightning Stroke.

TREACHER, W. H.—Annual Report, Federated Malay States, 1903.

VALLOT, J.—J. Vallot et son œuvre.

VINCENT, J.—Aperçu de l'histoire de la météorologie en Belgique, parts 1 and 3.—Études sur les nuages, III.—Notes bibliographiques sur les nuages.

WAGSTAFFE, W. W.—Summary of Weather for 1903 at Sevenoaks.

WARD, R. DE C.—Sensible Temperatures.—The Annual and Geographical Distribution of Cyclones of High Velocity in the United States, 1893-1902, by S. Hanzlik.—The Climatology of the United States: an Outline.

WARRY, (Dr.) J. K.—Report on the Sanitary Condition of the Hackney District, 1902.

WATZOF, S.—Tremblements de Terre en Bulgarie, No. 4.

WILLCOCKS, (Sir) W.—The Assuân Reservoir and Lake Moeris.

WRAY, C.—Pahang Administration Report, 1903.

LANTERN SLIDES.

BAXENDALL, J.—Evaporation Tank (2 slides).—Halliwell's Self-recording Rain Gauge (2 slides).

ELLIS, W.—Auroræ and Magnetic Disturbance (2 slides).

MAWLEY, E.—Phenological Observations, 1903 (11 slides).

NEWMAN, T. P.—Clouds and Meteorological Diagrams (7 slides).

ROTCH, A. L.—Instrument for determining the Direction of the Wind at Sea (3 slides).

PHOTOGRAPHS.

HANDS, A.—Godshill Church, struck by Lightning, Jan. 4, 1904 (8 photos).

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 15, 1905.

Ordinary Meeting.

RICHARD BENTLEY, F.S.A., President, in the Chair.

FRANCIS ALEXANDER BARTON, L.R.C.P., Alexandra Palace, N.;
NATHAN GYLES, 8 Young Street, Doncaster;
FREDERICK WILLIAM HARMER, F.G.S., Cringleford, Norwich;
Major ARTHUR DILLON DENIS KELLY, Weston, Duleek, Co. Meath;
JOSEPH MALCOLM KERR, Assoc.M.Inst.C.E., Gokak Falls, India; and
Capt. EDWARD ROBERT M'KINSTRY, Bod-ynys, Holyhead,
were balloted for and elected Fellows of the Society.

The PRESIDENT, Mr. RICHARD BENTLEY, delivered an Address on "THE GROWTH OF INSTRUMENTAL METEOROLOGY" (p. 173).

Mr. W. MARRIOTT exhibited some lantern slides illustrating Meteorological Phenomena, etc.

It was resolved that the thanks of the Society be communicated to the President and Council of the Institution of Civil Engineers, for permitting the Exhibition of Instruments to be held in their Library, and also to the various Exhibitors.

The Fellows and their friends then proceeded to the Library of the Institution of Civil Engineers to inspect the Exhibition of Meteorological Instruments (p. 194).

April 19, 1905.

Ordinary Meeting.

RICHARD BENTLEY, F.S.A., President, in the Chair.

EDWARD PHELPS ALLIS, Jun., LL.D., Mentone, France;
Capt. CHARLES B. ANDERSSON, Haydon Bridge, Northumberland;
JAMES ASPINALL, Westbourne Grove, Harpurhey, Manchester;
JOSEPH BURTT DAVEY, F.L.S., Pretoria, Transvaal;
HENRY EDGEWORTH FRICK, Quincey, Mass., U.S.A.;
ARTHUR ERNEST HAYTER, Honiton, Devon;
SPENCER COWPER RUSSELL, 2 Park Villas, Ashley Road, Epsom;
GEORGE CLARKE SIMPSON, B.Sc., University, Manchester;
Capt. HERBERT MARRIOTT WALKER, 228 Mackenzie Road, Beckenham;
Capt. GEORGE SALKELD WEBSTER, Bootle, Liverpool; and
HENRY DALA WILLIAMSON, Yokohama, Japan;
were balloted for and elected Fellows of the Society.

The following communications were read:—

1. "AN ACCOUNT OF THE OBSERVATIONS AT CRINAN IN 1904, AND DESCRIPTION OF A NEW METEOROGRAPH FOR USE WITH KITES." By W. H. DINES, B.A., F.R.S., F.R.Met.Soc. (p. 217).

2. "RATE OF FALL OF RAIN AT SEATHWAITE." By HUGH ROBERT MILL, D.Sc., LL.D., F.R.Met.Soc. (p. 229).

CORRESPONDENCE AND NOTES.

The Meteorological Office.

The following Treasury Minute, dated May 20, 1905, dealing with the constitution of the Meteorological Office, has been issued as a Parliamentary Paper [Cd. 2559] :—

My lords resume consideration of the report of the committee presided over by Sir Herbert Maxwell on the administration of the Meteorological Office.

Since the issue of the report my lords have been in communication with the Royal Society, the Board of Admiralty, the Board of Trade, and the Board of Agriculture and Fisheries, and they are now in a position to place on record the conclusions at which they have arrived.

1. The Meteorological Office will, as from April 1, 1905, be placed under the management of a committee constituted as follows :—

The director of the Meteorological Office,
Two members nominated by the Royal Society,
The Hydrographer of the Navy,
One member nominated by the Board of Trade,
One member nominated by the Board of Agriculture and Fisheries,
One member nominated by the Treasury.

The members of the committee will be appointed by the Treasury and, subject to the discretion of the authorities by which they are respectively nominated, will hold office for a period not exceeding five years, but will be eligible for reappointment.

2. The director will be appointed by the Treasury, and will receive out of the grant-in-aid a salary of £800, rising after five years to £1000 per annum, without a title to pension. He will hold office for a period of five years, but, like the other members of the committee, will be eligible for reappointment until he attains the age of sixty-five. The present director will receive the *maximum* of the scale, namely, £1000 per annum, from April 1, 1905.

3. Subject to the general control of the committee and to such regulations as may be laid down by the Treasury, the director will be responsible for the administration of the office.

4. The director will act as chairman of the committee, and will summon it at such times as he considers it desirable ; but four meetings at least shall be held during the year.

5. The members of the committee will not receive remuneration for their services, but travelling and subsistence expenses will be allowed in the case of members not residing in the metropolis.

6. My lords will ask Parliament annually to vote a grant-in-aid of the expenses of the office. For the present this grant is fixed at £15,300.

7. The grant will be administered by the committee, who may, with the consent of the Treasury, delegate to the director such powers of expenditure as they consider proper. All cheques will be signed by the director and countersigned by a member of the committee.

8. The committee will make an annual report for presentation to Parliament, and will at the same time transmit to the Treasury a statement of their accounts in such form as may be prescribed. In December of each year the committee will submit a statement showing the manner in which it is proposed to apply the grant for the ensuing financial year.

9. The staff will be appointed and their salaries fixed by the committee on the recommendation of the director.

10. In the absence of the director the committee may appoint one of its members to act as interim director.

METEOROLOGY AT THE ROYAL AGRICULTURAL SOCIETY'S SHOW, PARK ROYAL, *June* 27–30, 1905.

FIG. 1.—Meteorological Exhibit.

FIG. 2.—Climatological Station.

11. My lords are pleased to appoint the following gentlemen to be members of the Committee :—

Mr. W. N. Shaw, Sc.D., F.R.S., Director.

Capt. Arthur M. Field, R.N., Hydrographer to the Navy.

Capt. A. J. G. Chalmers, Professional Officer of the Marine Department, Board of Trade.

Mr. W. Somerville, Sc.D., Assistant Secretary of the Board of Agriculture and Fisheries.

Professor G. H. Darwin, F.R.S., University of Cambridge.

Professor Arthur Schuster, F.R.S., University of Manchester.

Mr. G. L. Barstow, nominated by the Treasury.

Meteorology at the Royal Agricultural Society's Show, 1905.

The Royal Agricultural Society decided this year to include a section of Meteorology in the Agricultural Education and Forestry Exhibition, which was held in connection with the Show at Park Royal, June 27 to 30.

The Royal Meteorological Society was invited to undertake the arrangements for this new departure.

This section, which was arranged under the supervision of Mr. W. Marriott, contained the following exhibits :—

Lent by the Royal Meteorological Society.

1. Diagrams :—

Monthly Rainfall at Greenwich, 1815 to 1904.
Depth of Water in a Well and Rainfall, Cirencester, 1887 to 1902.
Monthly Temperature of the Air and of the Earth at 1 and 4 feet deep, in Clay, in Sand, and in Chalk.
Temperature and Rainfall when the produce of Wheat was (1) Highest, and (2) Lowest, at Rothamsted.
Temperature and Rainfall when the produce of Hay was (1) Highest, and (2) Lowest, at Rothamsted.
Maps showing Hours of Bright Sunshine recorded in England and Wales: (1) Average, 1881 to 1900; (2) 1904.

2. Photographs and Drawings illustrating Meteorological Phenomena :—

Clouds, Lightning, Damage by Lightning, Hail, Damage by Hail, Snow, Frost, Floods, Drought, Damage by Gales, Tornadoes, and Whirlwinds.

3. Models of large Hailstones, 7 inches in circumference, which fell near Montreaux, France, August 15, 1888.

4. Boots of Man struck by Lightning.

5. Portion of Tree damaged by Whirlwind in Wiltshire, October 1, 1899.

6. Portraits :—

James Glaisher, F.R.S., Founder of the Royal Meteorological Society.
Admiral R. FitzRoy, F.R.S., Originator of "Storm Warnings."
G. J. Symons, F.R.S., Founder of the British Rainfall Organisation.

7. Publications :—

Specimens of Meteorological Publications issued in the British Isles which contain information of use to Agriculturists.

8. Mercurial Barometer (Kew pattern).

Lent by Dr. W. N. Shaw, F.R.S., Meteorological Office, 63 Victoria Street, S.W.

9. Diagrams :—

The Course of the Seasons in the British Isles. Weekly Averages for the 20 years, 1881 to 1900, and also for the current year.
Yield of Wheat, England, and Autumn Rainfall, 1884 to 1905.
Warmth of the Seasons, 1884 to 1904, and the Barley Crop, Eastern Counties.

10. Maps showing passage of a Storm-centre across the South of England, and the Meteorological Records from the Self-Registering Instruments at Falmouth Observatory, February 16-17, 1904.

The current day's Weather Map and Forecasts was posted up each afternoon.

Lent by Dr. H. R. MILL, F.R.S.E., 62 Camden Square, N.W.

11. Rainfall Maps of the British Isles :—

1. Mean Annual Rainfall, 1870 to 1899.
2. Rainfall of the Wettest Year, 1872.
3. Rainfall of the Driest Year, 1887.

Lent by Mr. W. MARRIOTT, F.R.Met.Soc., 70 Victoria Street, S.W.

12. Diagrams illustrating Monthly Distribution of Rainfall, according to altitude up to 1000 feet above sea-level, in the East and West of England.

Lent by Messrs. NEGRETTI and ZAMBRA, Holborn Viaduct, E.C.

13. Instruments :—

Dry and Wet Bulb Thermometers.
Maximum Thermometer.
Minimum Thermometer.
Grass Minimum Thermometer.
Earth Thermometers (1 and 4 feet).
Snowdon Rain Gauge and Camden Measuring Glass.
Campbell-Stokes Sunshine Recorder.
Jordan Photographic Sunshine Recorder.
Robinson Anemometer for registering the Velocity of the Wind.
Barograph.
Thermograph.
Dry and Wet Bulb Thermograph.
Self-Recording Hair Hygrometer.
Self-Recording Rain Gauge.

Lent by Mr. J. J. HICKS, F.R.Met.Soc., 8 Hatton Garden, E.C.

14. Instruments :—

Campbell-Stokes Sunshine Recorder (Curtis's Pattern).
Solar Radiation Thermometers.
Grass Minimum Thermometers.
Dines's Meteorograph for use with Kites.

Lent by Mr. F. L. HALLIWELL, 5 Roe Lane, Southport.

15. Halliwell's Self-Recording Rain Gauge.

TYPICAL CLIMATOLOGICAL STATION. (Outside the Exhibition Building.)

Enclosure with Instruments necessary for the equipment of a Climatological Station of the Royal Meteorological Society, viz. :—

1. Stevenson Thermometer Screen, fitted with Dry Bulb, Wet Bulb, Maximum, and Minimum Thermometers.
2. Snowdon Rain Gauge and Measuring Glass.
3. Black and Bright Bulb Thermometers.
4. Grass Minimum Thermometer.
5. Campbell-Stokes Sunshine Recorder.
6. Earth Thermometers (1 and 4 feet).

Mr. W. Marriott gave an Address on "Meteorology in Relation to Agriculture" each day at 3 p.m. at the typical Climatological Station adjoining the Exhibition.

On the first day (Tuesday) H.R.H. the Prince of Wales spent some time in looking over the exhibits, and on the second day (Wednesday) H.M. The King and H.R.H. Princess Victoria also visited the section and were much interested in it.

Fig. 1 (Plate 10) gives a view of a portion of the Meteorological Section, and Fig. 2 shows the Climatological Station (20 feet square) outside the Exhibition building.

Whirlwinds in Cheshire, June 26 and 28, 1905.

HOLMES CHAPEL.—A curious atmospheric disturbance was observed on the estate of the College of Agriculture at Holmes Chapel shortly before 3 p.m. on Monday, June 26. A number of students were engaged in watching a swarm of bees, when their attention was drawn to one of the hayfields, which had been cut the same morning. In the centre of the field was a column of hay, with breaks in it at intervals, rising to a height of nearly a thousand feet, revolving at a terrific rate. The disturbance lasted for about ten minutes, and on going to the field the students found that all the hay had been practically removed for a radius of 12 to 20 feet from the centre of the field, where the base of the whirlwind had been. The wind was due North-east in the morning, and due South in the afternoon The sky was somewhat hazy and overcast at times, but no rain had fallen.

NORTHWICH.—A singular accompaniment of the storm in Cheshire on Wednesday, June 28, was a whirlwind about noon, which wrought extraordinary and fantastic havoc in the neighbourhood of Northwich. First came a shower of hail, and then the wind swept across the river Weaver in a great circle, the centre of which was an absolute calm. The whirlwind is described as having lasted only a few moments. A cloud of dust and cinders darkened the sky as it swept along with irresistible force. A slaughter-house was unroofed, and another nearly dismantled, a clothing store was wrecked, the Northwich Gas-works was unroofed, telephone wires were snapped, the corner of a cottage was thrown down, and the ends of two other houses were blown away, a tree was blown across one of the thoroughfares, a ton of hay, part of a 15-ton stack, was carried a quarter of a mile, the railway station bookstall was swept clear, some of the contents being afterwards found in a field 300 yards away, and a lady cyclist was blown into a fence. Curiously enough, at Knutsford, Middlewich, and Winsford, which are all near Northwich, there was not the slightest sign of the whirlwind.

RECENT PUBLICATIONS.

The Outlines of Tropical Climatology. By LIEUT.-COL. G. M. GILES, M.B., F.R.C.S. 8vo. 109 pp. London, 1904.

This pamphlet was originally intended to serve only as an appendix to the author's book, *Climate and Health in Hot Countries*, but as it contained data which was not readily accessible, he decided to make it a work by itself. The author includes under the general term, "hot climates," practically the whole of Africa, much of South America, the Southern States of North America with the West Indian Islands, Asia Minor, Arabia, Persia, India, and the Malay Peninsula, the greater part of China, Australia, and the islands lying between it and the continents of the northern hemisphere. He points out that the following are the most important data in forming an opinion of the characters of a given climate:—

1. The mean temperature of each month.
2. The mean monthly daily range of temperature, or, what is practically as valuable, the mean maxima and minima.
3. The relative humidity of the air.
4. The monthly rainfall.
5. The number of rainy days in each month.
6. The average condition of the sky, whether clear or overcast, in each month.

7. The amount and daily distribution of wind.

Section II. is devoted to "the special characteristics of the climates of certain hot countries." Numerous tables are given containing the monthly temperatures, relative humidity, rainfall, etc., at various places in each country.

This work supplies a long-felt want by giving monthly values from so many places, and is rendered more valuable to all classes of readers by the data being in both the English and the Continental scales.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of general interest.

For a full Bibliography the reader is referred to the *International Catalogue of Scientific Literature.*

Angstrom, K.—An Instrument for the Measurement of the Radiation from the Earth. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (462-463).

Arctowski, H.—La météorologie des regions antarctiques et la co-opération internationale dans les explorations polaires. *Ciel et Terre, Brussels*, **25**, 1904-5 (581-585).

Arendt, T.—Gewitter und Hagelgefahr. *Wetter, Berlin*, **22**, 1905 (49-55, 73-82).

Arendt, T.—Verwendung des Wellman'schan Doppelbildmikrometers zu meteorologischen Zwecken. *Meteor. Zeits., Vienna*, **22**, 1905 (185-187).

Arendt, T.—Über die Gewitterverhältnisse des Brocken. *Meteor. Zeits. Vienna*, **22**, 1905 (223-229).

Assmann, J.—Die Niederschlagsverhaltnisse in Zentral-Europa in der ersten November-Dekade 1904. *Wetter, Berlin*, **22**, 1904 (68-70).

Bacon, Rev. J. M.—Upper Air Currents and their Relation to the Audibility of Sound. *Rep. Brit. Assoc.* **1904**, *London*, 1905 (482).

Barth, P.—Das Wetter auf dem nordatlantischen Ozean vom 25 September bis zum 13 Oktober, 1903. *Ann. d. Hydrog. u. Marit. Met.*, *Berlin*, **33**, 1905 (97-112).

Bates, D. C.—Meteorological Averages and Extremes at Wellington, New Zealand. *Symons' Met. Mag., London*, **40**, 1905 (64).

Bauer, L. A.—Projet de levé d'une carte magnétique du nord de l'océan Pacifique. *Ciel et Terre, Brussels*, **26**, 1905 (1-5).

Bennett, W. J.—The Storm and Cold Wave of December 24-29, 1904. *Monthly Weather Rev., Washington*, **32**, 1904 (561-562).

Berthoud, P.—Météorologie de Lourenço Marques. *Bol. Soc. de Geog. Lisboa*, **22**, 1904 (390-391, 438-439); **23**, 1905 (38-39).

Besson, L.—L'ascension scientifique du 1er Mars 1905. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (91-94).

Brodie, F. J.—The Weather during the Agricultural Year, 1903-1904. *J. R. Agric. Soc. London*, **65**, 1904 (381-392).

Brown, R. N. R.—Argentine Antarctic Station. *Scot. Geog. Mag. Edinburgh*, **21**, 1905 (207-210).

Buchan, A.—Meteorological Observations on Ben Nevis. (Report of the British Association Committee.) *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (55-60).

Buchanan, G. Y.—Historical Remarks on some Problems and Methods of Oceanic Research. *Proc. Roy. Inst. London*, **17**, 1905 (357-374).

Buckley, C. W.—Climatology from a Medical Standpoint. *Baln. Clim. J., London*, **9**, 1905 (98-114).

Burtt, T.—Meteorological Observations in Pemba during 1903 and 1904. *Symons' Met. Mag., London*, **40**, 1905 (34-35).

Cave, Miss E. F.—The Application to Meteorology of the Theory of Correlation. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (481).

Chree, C.—An Analysis of the Results from the Falmouth Magnetographs on "quiet" Days during the Twelve Years 1891 to 1902. *Phil. Trans. Roy. Soc. London*, Series A. **204**, 1905 (373-406).

Clayton, H. H.—The Diurnal and Annual Periods of Temperature, Humidity and Wind-velocity up to 4 Kilometers in the free Air, and the average vertical Gradients of these Elements at Blue Hill. *Ann. Astr. Obsy. Harvard Coll., Cambridge, Mass.*, **58**, 1904 (1-62).

Conrad, V.—Ueber die Elektrizitäts—Zerstreuung auf dem Sonnblick. *Meteor. Zeits., Vienna*, **22**, 1905 (173-175).

Cornish, V.—Terrestrial Surface Waves and Wave-like Surfaces. Report of the British Association Committee. *Rep. Brit. Assoc.*, **1904**, *London*, 1905, (301-302 and pl.).

Crosthwait, H. L.—A Journey to Lake San Martin, Patagonia. *Geog. J., London*, **25**, 1905 (286-291 and spl.)

Dansey, R. P.—The Glacial Snow of Ben Nevis. *Symons' Met. Mag., London*, **40**, 1905 (29-32).

Dechevrens, M.—La variation diurne de la tension de la vapeur d'eau à Jersey. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (89-91).

Dines, W. H.—Investigation of the Upper Atmosphere by means of Kites in Co-operation with a Committee of the Royal Meteorological Society. (Report of the British Association Committee.) *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (17-20).

Don, J.—A Correlation between the Electric Conductivity of Air and the Variation of Barometric Pressure. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (469-471 and pl.).

Dufour, C.—Le climat des Philippines. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (51-56).

Eddy, W. A.—Perpendicular Cold Air Movements as related to Cloud Velocity. *Monthly Weather Rev., Washington*, **32**, 1904 (559-560).

Eliot, Sir J.—Opening Address to Subsection of Cosmical Physics [Indian and Imperial Meteorology.] *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (443-457).

Eliot, Sir J.—A Preliminary Investigation of the more Important Features of the Meteorology of Southern Asia, the Indian Ocean, and Neighbouring Countries during the Period 1892-1902. *Indian Met. Mem., Calcutta*, **16**, 1905 (186-307 and Appendix i.-xlvii. and 22 pl.).

Ellis, W.—The Seasonal Variation in Magnetic Disturbance, with other Remarks. *Mon. Not. R. Astr. Soc., London*, **65**, 1905 (520-524).

Farr, C. C.—On some continuous Observations of the Rate of Dissipation of Electric Charges in the Open Air. *Proc. Roy. Soc. London, A.*, **75**, 1905 (152-159).

Forbes, N. H.—Observations on the Climate and Health Resorts of Scotland. *Baln. Clim. J., London*, **9**, 1905 (65-87).

Fox, F.—The Boring of the Simplon Tunnel, and the Distribution of Temperature encountered. *Proc. Roy. Soc. London, A.*, **76**, 1905 (29-33).

Friesenhof, G.—Neue Form der Wetterkarten und ihr Ergebnis. *Meteor. Zeits., Vienna*, **22**, 1905 (234-235).

Frühling, J.—Der Nordsturm an der ostdeutschen Küste vom 13 und 14 Januar 1905. *Ann. d. Hydrog. u. Marit. Met., Berlin*, **33**, 1905 (113-116 and 2 pl.).

Gockel, A.—Über den Ionengehalt der Atmosphäre und dessen Zusammenhang mit Luftdruckänderungen. *Meteor. Zeits., Vienna*, **22**, 1905 (97-102).

Hands, A.—Are Lightning Conductors a Source of Danger? *Elect. Rev., London*, **56**, 1905 (758).

Hann, J.—Die Anomalien der Witterung auf Island in dem Zeitraume, 1851-1900, und deren Beziehungen zu den gleichzeitigen Witterungsanomalien in Nordwesteurope. *Meteor. Zeits., Vienna*, **22**, 1905 (64-77).

Hann, J.—Zum Klima der aquatorialen Westküste Afrikas. *Meteor. Zeits., Vienna*, **22**, 1905 (120-127).

Hanzlik, S.—The new "Meteorologia," by A. J. Woeikof. *Monthly Weather Rev., Washington*, **32**, 1904 (554-555).

Hanzlik, S.—Some Relations between Direction and Velocity of Movements and Pressure at the Centre of Ellipsoidal Cyclones. *Monthly Weather Rev., Washington,* **32,** 1904 (562-565).

Harvey, C. W.—A Quarter of a Century's Rainfall at Throcking, Herts. *Symons' Met. Mag., London,* **40,** 1905 (32).

Hedges, K.—Modern Lightning Conductors. *J. Soc. Arts, London,* **53,** 1905 (726-742).

Helicar, N. G.—A Home-made Barometer. *Daily Graphic, London,* April 8, 1905.

Hennig, R.—Sturmfluten der Ostsee. *Wetter, Berlin,* **22,** 1905 (34-36).

Herbertson, A. J.—The Major Natural Regions: an Essay in Systematic Geography. *Geog. J., London,* **25,** 1905 (300-310).

Herrera, G. E.—Clima de la Amazonía. *Bol. Soc. Geog. Lima,* **15,** 1904 (87-93).

Hopkinson, J.—The Rainfall of the Midland and Eastern Counties of England. *Rep. Brit. Assoc.,* **1904,** *London,* 1905 (483-485).

Hopkinson, J.—The Rainfall of England, 1861-1900. *Rep. Brit. Assoc.,* **1904,** *London,* 1905 (485-487).

Jaufmann, J.—Über Radioaktivität von atmosphärischen Niederschlägen und Grundwässern. *Meteor. Zeits., Vienna,* **22,** 1905 (102-113).

Johansson, O. V.—Zur Definition des Rauhfrostes und Glatteises. *Meteor. Zeits., Vienna,* **22,** 1905 (27-29).

Johansson, O. V.—Uber den Zusammenhang der meteorologischen Erscheinungen mit Sonnenfleckenperioden. *Meteor. Zeits., Vienna,* **22,** 1905 (145-158).

Kassner, C.—Der Globus in der Meteorologie. *Wetter, Berlin,* **22,** 1905 (25-32).

Kerner, F. v.—Messung der täglichen Temperaturbewegung in einem Küstenflusse des Karstes in Dalmatien. *Meteor. Zeits., Vienna,* **22,** 1905 (77-80).

Kerner, F. v.—Ueber die Abnahme der Quellentemperatur mit der Höhe. *Meteor. Zeits., Vienna,* **22,** 1905 (159-164).

Kesslitz, W.—Wetterkartenindex als Hilfsmittel für die Wetterprognose. *Meteor. Zeits., Vienna,* **22,** 1905 (183-185).

Kimball, H. H.—Evaporation Observations in the United States. *Monthly Weather Rev., Washington,* **32,** 1904 (556-559).

Kimball, H. H.—The Co-ordinates of the United States Weather Bureau Station at Mount Weather, Va. *Monthly Weather Rev., Washington,* **33,** 1905 (9-10).

Knies, E.—Der mittlere Gang der Luftwärme zu V. d. Heydt bei Saarbrücken. *Meteor. Zeits., Vienna,* **22,** 1905 (83-85).

Krebs, W.—Verdunstungsmessungen mit dem Doppelthermometer für Klimatologische und hydrographische Zweeke. *Meteor. Zeits., Vienna,* **22,** 1905 (211-221).

Lampfert, R. G. K.—On a Form of Sudden Weather Change. *Symons' Met. Mag., London,* **40,** 1905 (41-44).

Lemström, S.—On the Effect of Electric Air-Currents. *Rep. Brit. Assoc.,* **1904,** *London,* 1905 (482-483).

Lockyer, W. J. S.—The Short Period Barometric See-Saw and its Relation to Rainfall. *Rep. Brit. Assoc.,* **1904,** *London,* 1905 (459-460).

Lyons, H. G.—On the Relation between Variations of Atmospheric Pressure in North-east Africa and the Nile Flood. *Proc. Roy. Soc. London, A.,* **76,** 1905 (66-86 and pl.).

Maillet, E.—Les crues en 1903 sur la Seine, la Saone, le Rhone et le Rhin. *Ann. Soc. Mét. France, Paris,* **53,** 1905 (104-105).

Marchand, E.—Les leurs crépusculaires et phénomènes connexes observés en 1902, 1903-1904 dans les Pyrénées. *Ann. Soc. Mét. France, Paris,* **53,** 1905 (40-45).

Marchand, E.—Les périodes d'agitation seismiques de juillet, août et septembre, 1904, dans les Pyrénées. *Ann. Soc. Mét. France, Paris,* **53,** 1905 (94-104).

Maunder, E. W.—L'origine solaire des perturbations du magnétisme terrestre. *Ciel et Terre, Brussels,* **26,** 1905 (54-56).

Maunder, E. W.—Magnetic Disturbances as recorded at the Royal Observatory, Greenwich, and their Association with Sun-Spots. Second Paper. *Mon. Not. R. Astr. Soc., London,* **65** (538-559 and pl.).

Maurer, J.—Beobachtungen über die irdische Strahlenbrechung bei typischen Formen der Luftdruckverteilung. *Meteor. Zeits., Vienna*, **22**, 1905 (49-63).

Mecking, L.—Die Strömungen an den südlichen und südöstlichen Küsten von Neufundland. *Ann. d. Hydrog. u. Marit. Met., Berlin*, **33**, 1905 (145-150).

Meteorologische Beobachtungen in Boroma (Südafrika). *Meteor. Zeits., Vienna*, **22**, 1905 (170-172).

Michel, F.—Einige Verbesserungen am Kondensations-hygrometer. *Meteor. Zeits., Vienna*, **22**, 1905 (187-189).

Mill, H. R.—On the Unsymmetrical Distribution of Rainfall about the Path of a Barometric Depression. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (480-481).

[Mill, H. R.].—The Rainfall of the Six Months, September 1904–February 1905. *The Times. Symons' Met. Mag., London*, **40**, 1905 (21-25).

Miller, E. R.—Solar Halo of February 3, 1905, at Washington, D.C. *Monthly Weather Review, Washington*, **33**, 1905 (11-13).

Monti, V.—Sulla distribuzione dei temporali e della grandine in Italia a seconda dei luoghi e delle stagioni. *Ann. Uff. Cent. Met. Ital. Rome*, **20**, 1898 (B 1-270), 1902.

Moore, Sir J. W.—Earth Temperature and Diarrhœal Diseases in Dublin in 1904. *Dublin J. of Medical Science*, May 1905.

Muir, J. S.—Notes on the Weather on the Vatna Jökull during August and September 1904. *J. Scot. Met. Soc., Edinburgh*, **13**, 1905 (33-37).

New Scheme for the Advancement of Meteorological Knowledge. *Symons' Met. Mag., London*, **40**, 1905 (61-62).

Nordmann, C.—Enregistreur à écoulement liquide de l'ionisation atmosphérique. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (64-66).

Pochettino, A.—Su alcune esperienze sul wetterschiessen es guite nel luglio 1901. *Ann. Uff. Cent. Met. Ital., Rome*, **21**, 1899, Appendice (A 1-12), 1904.

Pochettino, A.—Risultati degli studi compiuto durante l'anno 1900, 1901, nella stazione governativa di studio dei fenomeni temporaleschi e di controllo agli esperimenti grandinifughi. *Ann. Uff. Cent. Met. Ital., Rome*, **21**, 1899 (A 1-260 and 36 pl.); **22**, 1900 (A 1-481 and 35 pl.), 1904.

Pochettino, A.—Sull' andamento degli elementi meteorologici prima, durante e dopo lo svolgersi dell' attività temporalesca. *Ann. Uff. Cent. Met. Ital., Rome*, **22**, 1900. Appendice A (1-33 and 19 pl.), 1904.

Pochettino, A.—Si alcune osservazioni di meteorologia fisica. *Ann. Uff. Cent. Met. Ital., Rome*, **22**, 1900, 2*a* Appendice (A 1-37), 1904.

Quinet, Dr.—Les routes de migration des oiseaux. *Ciel et Terre, Brussels*, **26**, 1905 (75-89).

Raulin, V.—Sur les observations pluviometriques au Japon. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (67-73).

Rotch, A. L.—The Temperature of the Air in Cyclones and Anti-cyclones, as shown by Kite Flights at Blue Hill Observatory, U.S.A. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (468-469).

Rotch, A. L.—Ein Instrument zur Bestimmung der wahren Richtung und Geschwindigkeit des Windes auf See. Translated from *Q. J. R. Met. Soc.*, **30**, 1904, by R. Perlewitz. *Ann. d. Hydrog. u. Marit. Met., Berlin*, **33**, 1905 (120-122).

Royds, C. W.—On the Meteorology of the Part of the Antarctic Regions where the *Discovery* wintered. *Geog. J., London*, **25**, 1905 (387-391).

Sapper, K.—Ergebnisse der Regenmussungen im südlichen Guatemala. *Meteor. Zeits., Vienna*, **22**, 1905 (85-86).

Schuster, A.—On the Ionisation of the Atmosphere. *Rep. Brit. Assoc.*, **1904**, *London*, 1905 (471).

Scott, R. F.—Results of the National Antarctic Expedition.—Geographical. *Geog. J., London*, **25**, 1905 (353-370 and 5 pl.).

Shaw, W. N.—On the Treatment of Climatological Observations. *J. Scot. Met. Soc., Edinburgh*, **13**, 1905 (3-13 and 6 pl.).

Shaw, W. N.—On a Relation between Autumnal Rainfall and the Yield of Wheat of the following Year.—Preliminary Note. *Proc. Roy. Soc. London*, **74**, 1905 (552-553).

Shaw, W. N.—Effect of Autumnal Rainfall upon Wheat Crops. *Nature, London*, **71**, 1904-5, (470-471).

Simpson, G. C.—Atmospheric Electricity observed from Balloons. *Nature, London*, **72**, 1905 (92-93).

Southall, H.—Long-period Rainfall Averages. *Symons' Met. Mag., London*, **40**, 1905 (50-51).

Sprung, A.—Ueber die automatische Aufzeichnung der Regen-Intensität. *Wetter, Berlin*, **22**, 1905 (56-58).

Strachan, R.—On Rain-gauges. *Horological J., London*, **46**, 1903-4 (140-143, 155-159); **47**, 1904-5 (8-9, 20-23).

Strachan, R.—On Self-recording Rain-gauges. *Horological J., London*, **47**, 1904-5 (35-40, 61-68, 88-92).

Teisserenc de Bort, L.—Presidential address to the French Meteorological Society, Feb. 7, 1905. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (33-39).

Teisserenc de Bort, L.—Variation de la température quotidienne dans la haute atmosphère. *Ann. Soc. Mét. France, Paris*, **53**, 1905 (62-64).

Tenorio, F. de P.—Légère critique de l'abri "Pastrana" pour thermomètres. *Mem. Soc. Cient. "Antonio Alzate," Mexico*, **20**, 1903 (371-377).

Topolansky, M.—Einige Resultate der 20 jährigen Registrierungen des Regenfalles in Wien. *Meteor. Zeits., Vienna*, **22**, 1905 (113-119).

Wachenheim, F. L.—Die Hydrometeore des gemassigten Nordamerika. *Meteor. Zeits., Vienna*, **22**, 1905 (193-211).

Watt, A.—The Rainfall of the Ben Nevis Observatories. *J. Scot. Met. Soc., Edinburgh*, **13**, 1905 (14-32).

Wegemann, G.—Ursachen der vertikalen Temperatur-verteilung im Weltmeere unter besonderer Berücksichtigung der Wärmeleitung. *Ann. d. Hydrog. u. Marit. Met., Berlin*, **33**, 1905 (206-211).

Woolnough, G.—New Zealand: its Geographical and Meteorological Conditions considered in their bearing on Field Industries. *Queensland Geog. J., Brisbane*, **19**, 1904 (37-44).

QUARTERLY JOURNAL

OF THE

ROYAL METEOROLOGICAL SOCIETY

VOL. XXXI.] OCTOBER 1905 [No. 136

MEASUREMENT OF EVAPORATION.

By RICHARD STRACHAN, F.R.Met.Soc.

[Read May 17, 1905.]

RAINFALL, evaporation, and percolation, as everybody knows, are related. Rainfall is commonly considered to form the sum of evaporation and percolation: $R = E + P$. Consequently, if two of these quantities are found by experiment or observation, the other is taken as known. But this is not always the case. A month may be very dry, and still evaporation will go on at the expense of previous percolation,—and otherwise. A month may be excessively wet; then there may be a fourth item in the account—overflow. However, the equation holds good in most places for ordinary weather, normal months and seasons. If evaporation, also percolation, could be observed as readily and closely as is rainfall, then overflow could be detected and measured.

Unfortunately, at few observatories is it possible to make evaporation and percolation, either or both, the subject of experiments. It would seem therefore desirable to be able to estimate, empirically even, the probable amounts of them. Having so estimated, say, evaporation, and observed rainfall, percolation may be approximately inferred also. Such an estimate, it would seem, could only be of any use, when attempted at the end of a calendar month, where the usual meteorological observations are conducted hourly. Of the trying of experiments with meteorological data there can be no end, since they are so numerous. Here, however, is a problem for which the data are insufficient. No station could be found for which published data were sufficient for the apparent requirements of the problem. Where the data are practically sufficient, probably the evaporation required as a test has not been observed. At the stations where evaporation has been observed, data for the theoretical determination of its amount are almost entirely wanting. Where can be found the mean daily temperature of the water, or the mean hourly velocity of the air over its surface, which are necessary?

It is proposed to show how the problem may be attacked, with some resemblance of probable accuracy, by means of the data obtained at the Royal Observatory, Greenwich, in 1898. This year is selected because Symons's *British Rainfall* for 1898 contains data which afford an indirect test. It gives observed evaporations at Camden Square and Croydon which agree remarkably well, and it may be assumed that at the Royal Observatory about the same mean values might have been found.

The data which have been employed are comprised in the accompanying table; the columns, being numbered below, are explained as follows:—

1898.	Greenwich.							Evaporation.				Rothamsted.		
	Temperature.			Vapour Tension.			Calculated Evaporation.	Camden Sq.	Croydon.	Mean of Camden Sq. and Croydon.	Lowestoft.	Evaporation.	Percolation.	Rainfall.
	Ground.	Air.	Dew-point.	V	v	$V-v$								
	°	°	°	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	44·4	43·7	39·8	·285	·245	·040	·54	·19	·29	·24	·39	·38	1·93	2·31
February	43·3	41·3	35·4	·260	·207	·053	·72	·37	·62	·50	·74	·49	1·38	1·87
March	42·8	40·0	34·2	·248	·197	·051	·69	·51	·68	·60	1·07	·88	·93	1·81
April	52·4	48·1	40·3	·336	·250	·086	1·17	1·28	1·65	1·46	2·03	1·41	·55	1·96
May	55·7	52·0	45·1	·388	·301	·087	1·19	1·56	2·00	1·78	2·28	1·65	·52	2·17
June	61·8	57·8	49·7	·479	·357	·122	1·67	2·10	2·22	2·16	2·91	1·80	·49	2·29
July	66·3	61·9	52·1	·554	·390	·164	2·25	2·96	2·92	2·94	3·15	2·14	·65	2·79
August	69·9	64·8	55·1	·613	·435	·178	2·45	2·53	2·69	2·61	2·88	2·03	·56	2·59
September	68·6	62·0	52·0	·556	·388	·168	2·30	1·73	1·81	1·77	2·39	1·86	·83	2·69
October	56·9	53·9	49·3	·416	·352	·064	·87	·45	·78	·61	1·33	1·62	1·65	3·27
November	47·7	46·1	42·8	·312	·275	·037	·50	·11	·44	·28	·61	·87	2·07	2·94
December	46·8	45·8	41·1	·309	·258	·051	·69	·16	·28	·22	·51	·54	1·97	2·51
Year	54·7	51·4	44·7	·380	·296	·084	15·04	13·95	16·38	15·16	20·27	15·67	13·53	29·20
Column 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Column 1 specifies the months of 1898. All data are for that year except for Rothamsted. (*See p.* 279.)

Column 2 gives the mean temperature at noon by a thermometer on the ground, shaded. This has been taken as representing the temperature of water, which should be used, and be found from daily mean observations.

Column 3 gives the mean monthly temperature by the dry-bulb thermometer, supposed to give the vapour tension of evaporating water.

Column 4 gives the mean monthly dew-point temperature by the wet-bulb thermometer.

Column 5 is the vapour tension at the temperature of the air.
,, 6 is the vapour tension due to the temperature of the dewpoint
,, 7 is the quantity ($V - v$)
,, 8 is the evaporation due to Greenwich, calculated.
,, 9 ,, ,, at Camden Square, observed by G. J. Symons.
,, 10 ,, ,, at Croydon, observed by B. Latham.
,, 11 ,, ,, mean of Camden Square and Croydon.
,, 12 ,, ,, at Lowestoft, observed by S. H. Miller, but reduced as recommended by Symons in the ratio 122 : 100.

Column 13 is the evaporation at Rothamsted, mean of 29 years.
„ 14 „ percolation „ „ „
„ 15 „ rainfall „ „ „
Columns 13, 14, 15 are taken from R. H. Scott's memoir in *Quart. Journ. Roy. Met. Soc.* for 1900, p. 143.

According to the *Philosophical Magazine* for 1862, Thomas Tate deduced experimentally that evaporation from water varies in the same ratio as the difference between the dry- and wet-bulb thermometers; that it varies with the velocity of the air over its surface; that it varies with the pressure of the atmosphere, and consequently is affected by elevation; that the best radiators are the best vaporisers, so that radiation is effective all around. The thermometrical test can be applied to the above data, but is not adequate without the wind, while barometrical pressure varies too little from month to month to materially affect the results, and nothing can be known as to the effect of radiation unless results, day and night, of hourly observations from an exposed thermometer on the ground can be consulted.

By vapour tension is understood the elastic resistance which aqueous vapour offers to pressure. It varies with the pressure and with temperature. It has been calculated and tabulated for meteorological and physical purposes. For given temperatures, the table gives the vapour tension in inches of mercury at temperature 32°. It is evident that the weight of mercury which it can sustain may be expressed by an equal pressure from water. Mercury, at 32°, is 13·59 times heavier than water; consequently, $13{\cdot}59\ (V - v)$ is the corresponding column of water at 32°. The water which evaporates is at a mean daily temperature, a; and the dilatation of water, b, has been found. The depth of water evaporated in a month will therefore be $(V - v)\ 13{\cdot}59\ a\,.\,b$. V, v, and a are required to be true monthly mean values; but *here* a compromise must be made with a, taken only at noon, for want of better. The depth of water, at 32°, must be brought to the temperature of the ground by taking careful reckoning of the coefficient of dilatation, which is supposed to be ·00025 per degree above 39°. Hence, regarding the expansion down to 32° to increase at the same rate, let x be the depth at 39°, y at observed temperature; then, to take January, $x : {\cdot}5436 :: 1 : 1{\cdot}00175$, and $x : y :: 1 : 1{\cdot}00135$, this number being due to temperature 44°·4. Solving, $y = {\cdot}5436 \times {\cdot}99825 \times 1{\cdot}00135$.

No attention has been given to wind, as its velocity over the water-surface is unknown. It would tend to make the evaporation in inches of water greater than as deduced for each month and stated in column 8. This column compared with 11, mean of Camden Square and Croydon,—places at about the same elevation as the Royal Observatory, and not too distant, presumably, for the purpose,—shows that the monthly values differ, but not surprisingly,—considering the difference of position, the defect of data as regards temperature of water, and neglect of wind,—but the totals for the year are almost the same. Lowestoft supports the comparison favourably, though there evaporation is greater. Strange it is to note that the mean values for evaporation at Rothamsted for 29 years should be almost similar to those deduced by this simple formula.

Many formulæ have been proposed for calculating evaporation. All available have been tried, but not one has been found altogether suitable.

Mention may be made of some which seem to deserve attention. Baldwin Latham, in his paper to the Royal Meteorological Society (*Quarterly Journal*, 26, p. 53), recommended Pole's formula, $E = \frac{T^2 - t^2}{A(100 - W)}$, wherein T represents the mean annual temperature of the ground; t is the mean dew-point; A (apparently), the mean annual temperature of the air; W, the wind in miles per hour; E, the evaporation in inches per day. It seems to be applicable to Bombay, but not to hold good for this country.

J. R. Mann (*Proceedings of the Meteorological Society*, 5, p. 286) proposed two formulæ for calculating evaporation:

$$E = 1{\cdot}5\, D \sqrt{T\left\{1 - \left(\frac{e}{e'}\right)^{\frac{1}{4}}\right\}} \text{ and } E = \frac{G}{4666} \sqrt{T\left\{1 - \left(\frac{e}{e'}\right)^{\frac{1}{4}}\right\}};$$

in which E is the evaporation of water in inches per hour; T, the absolute temperature of the water, at its surface, evaporating, that is 460° + Fahr.; e, tension of vapour at the dew-point; e', vapour tension due to the temperature of the water evaporating; D, the density, or weight, of the issuing vapour due to the temperature of the water, in pounds per cubic foot; G, the weight in grains of a cubic foot of vapour due to the temperature of the water, as given in Table VI. of Glaisher's *Hygrometrical Tables*. He said of the second: "This formula is, I believe, quite accurate except under very exceptional atmospherical conditions"; and added, "Strong currents of air over the surface of the water increase the amount of evaporation, a very strong draught, of say 30 feet per second, doubling or tripling that calculated." He worked out an example by each formula, but did not state how he obtained D. For dry-bulb 74°·2, wet-bulb 70°, water 72°, he deduced ·0087 in. depth of water evaporated per hour, which would amount to 6·5 ins. for the month!

The case seems to be, the psychrometer shows conditions of evaporation at the instant, and it is only by taking a large number of instances, such as hourly for a month, that a fair average condition can be obtained; for, in strictness, vapour tension does not admit of arithmetical averages, since it does not progress by equal increments. However, practical monthly results may be found to approximate to accuracy. In this view the formula would have given, regarding the data as monthly values, 1·74 in. or so for the whole evaporation during the month.

Cleveland Abbe, in his *Treatise on Meteorological Apparatus and Methods*, dated 1888, p. 376, says: "The large masses required in the measuring operations of the evaporimeter renders this instrument important to the meteorologists as a means of ascertaining the average hygrometric condition of the air during a long interval. From this point of view, therefore, this becomes an integrating hygrometer, and demands a more minute theoretical investigation than has as yet been given to it."

Desmond FitzGerald, during 1876-82, near Boston, U.S., measured evaporation from "water in pans 14·85 ins. in diameter, in which one ounce of water is represented by a depth of ·01 in." Abbe says the observations are represented quite closely by the empirical formula $E = \{{\cdot}014(V - v) + {\cdot}0012(V - v)^2\}(1 + {\cdot}67W^{\frac{1}{2}})$, in which E is the depth of water in inches evaporated per hour. FitzGerald used the

approximate expression $E = \cdot 0166(V - v)(1 + \frac{W}{2})$, in which V is the vapour tension corresponding to the temperature of the water; v, the vapour tension for the dew-point in free air; W, the velocity of the wind measured by a Robinson's anemometer at the level of the water. "FitzGerald finds that the velocity recorded by an anemometer 30·5 feet above the water is three times that prevailing at the surface.

"Comparative observations made in the sunshine and the shade are equally well represented by the above formula. The evaporation from snow and ice was also measured with minuteness and found to be well represented by this formula.

"If, then, the temperature of the water is observed, so that V, E, and W are known, then the FitzGerald formula gives the average vapour tension in the free air during the time in which the evaporation was effected; for which purpose it may be written $v = V - \frac{60E}{1+\frac{W}{2}}$. This use of the evaporimeter, therefore, is additional to its ordinary use for engineering purposes, but implies that the temperature of the water and the velocity of the air at its surface be observed." As to how the formula has to be worked to get the satisfaction claimed for it is difficult to discover; no example has been shown.

Cleveland Abbe's *Studies in Deductive Methods*, year 1890, p. 120, again mentions FitzGerald, and now says V is for temperature of the *air*; and the coefficient "represents the average of the year." As to the effect of wind, he refers to T. Russell's experiments. "The Piche evaporimeter was whirled at different velocities on a whirling-machine through the still air of a large room, and a similar instrument was simultaneously observed at rest; hence resulted the following relative weights or depths of evaporation from the wet surfaces of the paper discs.

Miles per hour of Wind	0	5	10	15	20	25	30
Relative Evaporation	1·0	2·2	3·8	4·9	5·7	6·1	6·3."

Considering the hitherto wild indications given by evaporimeters, Abbe's proposal seems visionary, to use the data which they yield for the determination of v, though it is not certain that the theory of the psychrometer is sufficiently accurate to yield the correct dew-point, nor that vapour tension has been absolutely truly ascertained. The necessity, however, is made apparent of improving the accuracy of evaporimeters, and of the importance of achieving a standard instrument of this class. An electric-resistance thermometer might be connected with the evaporimeter to record a daily or monthly temperature curve. A small windmeter, tested against a Dines' tube anemograph, could be exposed near the water to register the velocity of the air. At observatories where the solar thermometer is self-recording, as at New York, hourly readings throughout the night, as well as the day, should be published; then, if near the water, the fairest possible estimate of temperature which affects evaporation would be secured.

DISCUSSION.

The CHAIRMAN (Capt. D. WILSON-BARKER) remarked that the subject dealt with by Mr. Strachan was an exceedingly interesting one, and one which perhaps had not engaged the attention of meteorologists as much as it deserved. At present the various formulæ employed were in a very chaotic condition, and the instruments in use were not comparable with each other. He thought it was a pity that a standard evaporimeter was not obtainable ; for even if the results from it were not strictly correct, yet they would be comparable with observations from similar instruments in other parts of the country.

Dr. H. R. MILL said the subject of evaporation was one of great importance and no less difficulty. He had carried on Mr. Symons' observations, and was not without hope of arriving at some definite conclusions from the readings. With regard to the difficulty of temperature, that was felt most when small evaporators were used, as small quantities of water get unduly heated, and do not represent the ordinary conditions of nature. The tank in which evaporation is measured must be of large size, and it should have a maximum and minimum thermometer immersed in the water, which should be read at frequent intervals, though this, he was sorry to say, was rarely done. The surface water when heated up has a tendency to float and remain at a higher temperature than that below during calm weather. When the wind blows, however, the conditions are different, and the hot surface skin is blown to one side, the colder water rises, and the water becomes completely mixed up, and so the temperature of the water is rendered more uniform. The variation in the range of temperature from one day to the next was very little, and the changes due to the expansion of the water were consequently so slight that they might be disregarded. The effect of wind, however, was another matter, and no doubt was responsible for the extraordinary differences observed in various parts of the country. A free exposure always gave a much greater evaporation, and that was probably the reason why the evaporation at Camden Square and Croydon, both of which were somewhat sheltered, was so much less than in the more open positions at Southwold and Downholland. In 1903 he (Dr. Mill) had placed a small Robinson anemometer 1 foot above the evaporation tank at Camden Square, and on glancing through the last 6 months' observations, it could be seen that with a high wind evaporation was increased irrespective of temperature. He thought Mr. Strachan's calculated temperatures for the winter months were a little too high, as the water was probably often frozen during that period. Another great difficulty to contend with was the impure state of the atmosphere in large towns, which resulted in an oily film being formed over the water. During a breeze this film was blown over on one side, but in a dead calm it covered the surface of the water, and no evaporation could take place. That was probably another reason why gauges in the country showed higher results than those in towns. The year under discussion in the paper, 1898, was a year with considerably less evaporation than usual at Camden Square, therefore its accordance with Mr. Strachan's calculations was all the more remarkable. He would like to see other years treated in the same manner, say a year with an evaporation of 19 ins., and another year with an evaporation of 12 ins. If Mr. Strachan's system could be applied with satisfactory results in such cases, it might be almost worth while to consider the possibility of doing without evaporimeters altogether.

Mr. BALDWIN LATHAM said the subject of evaporation was one to which he had given much attention. He thought the Fellows were much indebted to Mr. Strachan for his paper, although he did not agree with all the statements and the results set out in the paper. All calculations of evaporation were

liable to considerable errors. He did not think the taking of the temperature of the ground at Greenwich, at one inch in depth at noon, at all represented the true mean temperature of the water evaporated at Camden Square or Croydon. For six years, 1883 to 1888, he took the temperature of the water of his floating evaporator at 9.0 a.m., at noon, and at 9.0 p.m. The average temperature of the water at 9.0 a.m. was 48°·7, at noon 52°·9, and at 9.0 p.m. 49°·2 ; and the average temperature of the ground at Greenwich at one inch in depth at noon, for the same years was 50°·4. The mean of the three observations of the water temperature at Croydon was 50°·3. This temperature, however, was too high, as it did not take in any night temperatures. He had reason for believing that the 9 a.m. temperature of the water did not differ much from the mean temperature of the water, but was probably too high. The mean temperature of the air at Croydon in 1898 was 51°·4. The mean temperature of the air at 9.0 a.m. in the same year was 51°·7, and the temperature, also in the same year, of the water of the floating evaporator at 9.0 a.m. was 51°·2. The mean temperature of the ground at Greenwich at one inch in depth, taken as the mean temperature of the water, was given at 54°·7, which is much too high.

It was not possible to arrive at the true amount of evaporation from deducting the depth of water passing through a percolating gauge from the depth of rainfall, for the simple reason that for some months in a year no percolation takes place, the gauges are comparatively dry, and there is no water to evaporate. In the last ten years, 1895-1904, the annual rainfall at Croydon has been 24·40 ins. The quantity of water yearly passing through a chalk percolating gauge at the same place was 10·57 ins., the difference between rainfall and percolation being 13·83 ins., while the actual evaporation from the floating evaporator in the same period was 16·38 ins., and the old form of evaporator of small size completely surrounded with air evaporated 29·06 ins., or considerably more than the rainfall recorded. Under natural conditions the amount of evaporation taking place was much larger when water was left in contact with the ground and carried off by evaporation through vegetation on the surface. The evaporation from the Wandle area of Croydon of about 22 square miles was in the same ten years 19·26 ins. per annum on the average.

He thought that his own evaporating gauge at Croydon was in a better situation than that at Camden Square for securing accurate observations, and he had noticed with the Camden Square evaporator that the water was much discoloured, and coloured water would affect the results of evaporation. If evaporators had to be filled up with a hard town water supply by exposure it would soon colour up. With his own gauges he always took care that they were filled with clean rain water. In taking the temperature of the water of an evaporator, it was necessary that the temperature of the surface film should be ascertained, and the thermometer itself should be first wetted, otherwise it would take out a certain quantity of water every time it was used. A registering thermometer would not give the surface temperature, and we must not have anything floating on the water that would at all diminish the surface area, as evaporation depends upon the actual area of water surface exposed. It would appear that it was hardly necessary to use the formula given by the author of the paper, for if the tensional difference between the vapour-tension due, to the temperature of the air and the temperature of the dew-point, is multiplied by 13·59, to bring it into water instead of mercury, the difference in the calculated result in a year is but ·08 in., or it becomes 14·96 ins. instead of 15·04 ins. This method of calculating evaporation by taking the tensional difference between the temperature of the air and the dew-point has been practised for a long period, and in the volume of Colaba Observations of 1854 it will be seen

that Mr. Chambers in certain years calculated the evaporation in this way instead of observing it.

With reference to the observation made on Dr. Pole's formula, this formula was to be found in the *Minutes of Proceedings of the Institution of Civil Engineers*, vol. 39, p. 36, and in using this formula the coefficient A was a variable quantity increasing in the winter months. This formula no doubt was suggested to correspond with evaporation instruments that gave much larger results than those found by the modern evaporators, and probably if the coefficient in this formula was largely increased it would give results comparable with present observations.

There appeared in the paper a slight error with regard to the amount of evaporation with his gauge at Croydon, which is given as 16·38 ins. instead of 16·49 ins.; the difference appeared to be the amount of condensation, ·11 ins., measured in that year. In his judgment condensation ought not to be deducted from the actual observed evaporation. The condensation in 1898 was much below the average. The condensation measured on the average of the last ten years was ·30 inches per annum.

The subject of evaporation was a very important one, and he hoped with Captain Wilson-Barker that before long they would get a standard instrument which would be secure against the action of birds and animals drinking from the evaporators, or, as at one time he had to contend with, birds washing in the tank outside his floating evaporator and splashing the water into the evaporator.

Mr. R. STRACHAN, in reply, said that he would ask them to imagine an apparatus applied to water, so as to rise and fall with the surface-level, recording continuously the temperature there. A small self-recording wind-gauge just above the water could record on the same sheet. Such a record could be treated on the same plan as that obtained from the thermograph. By comparison with observed evaporation, from a reputed evaporimeter, during the same time, the records for a year would probably suffice to yield formulæ for hourly, daily, monthly, or any other periodical rate of evaporation. It is not unreasonable to expect that by the application of electricity, a thermopile, or a resistance thermometer, would effect the purpose. Even four-hourly observations of a thermometer, having its bulb just immersed in the water, an ordinary wind-gauge at the same time just over the water, might suffice. For the theoretical problem, in short, are required the tension of the rising vapour, the tension of the vapour already in the ambient air, and the velocity of the air-current. When satisfactory formulæ are devised, the recording apparatus could be used in standing water, as reservoirs and ponds, also in lakes, rivers, and the sea. Little or nothing had been done with regard to evaporation at sea, although something had been attempted by Dr. Black. Meteorological Logs, of the "Excellent" class, might be turned to account. He did not agree with Dr. Mill as to the winter, for then the mean temperature of the air most nearly gave the temperature of water. He would like to see the investigation of Dr. Pole's formula, for it gave the annual evaporation at Bombay apparently with approximate accuracy. As to the figures for Croydon, they were as given by Mr. Symons. Balzac is reported to have said, "the genius of observation is almost the whole of human genius," well the remainder should be for improvement. Observers have been reasoning backward, let men begin to reason forward.

ON A LOGARITHMIC SLIDE-RULE FOR REDUCING READINGS OF THE BAROMETER TO SEA-LEVEL.

By JOHN BALL, Ph.D., B.Sc., F.G.S., Assoc.M.Inst.C.E.

[Read May 17, 1905.]

1. *Introduction.*

THE recent institution by the Egyptian Government of a considerable number of meteorological stations in Egypt and the Soudan has involved the performing at Helwan Observatory of large numbers of reductions to sea-level of barometric readings for the purpose of preparing isobaric charts. These reductions being generally based on the monthly means of observations taken thrice daily, the data are sufficiently accurate to warrant the corrections being computed with a fairly high degree of precision. At first they were calculated by Angot's method, using the *International Tables*; but the necessary interpolations were found to be laborious, while the accuracy attained was occasionally somewhat below that required. Recourse was then had to the logarithmic tables in the same volume; these left nothing to be desired in point of accuracy, but they involved more labour than was convenient. Attempts were then made by the author to devise some mechanical means of calculation which, whilst equally accurate in its results, should be quicker and less liable to errors of computation than the method by the logarithmic tables. These attempts were successful. A slide-rule for each station was devised, which met all requirements, and which could easily be prepared in the observatory office. Reductions are now made with the aid of these rules in less than one-tenth of the time previously occupied, and with a very high order of accuracy.

In the belief that it may be useful to others who have to perform similar reductions, it is proposed in the present paper[1] to describe the method of constructing such slide-rules, so that similar instruments can be readily made by any one to suit any given meteorological station. The instruments used at Helwan are adapted for metric measures; but in this paper the British system of measures will be adopted as more useful to British meteorologists. When an observed barometric height is mentioned in what follows, the reading is of course supposed to have been already reduced to 32° F. from the reading of the attached thermometer of the instrument, and also corrected for the effect on the height of the mercury-column of the variation of gravity with latitude and altitude.[2]

2. *Principle of the Method.*

The barometric formula employed in the *International Meteorological Tables*, based on Rühlmann's modification of Laplace's formula, is

$$Z=K(1+\epsilon+a\theta)\left(\frac{1}{1-\beta}\right)(1+\gamma)\left(1+\frac{Z+2z}{R}\right)\log\frac{H_0}{H} \quad . \quad . \quad . \quad . \quad (1),$$

[1] Communicated by permission of Capt. H. G. Lyons, Director-General of the Egyptian Survey Department.

[2] The barometric formula itself contains factors involving the variation of gravity, but those are of course for the effect on the weight of the *air-column*, not on the mercury.

where

Z = altitude of upper station,
z = altitude of lower station,
K = the barometric constant,
R = the mean terrestrial radius,
$\epsilon = \frac{5}{4}\frac{K}{R} \log e$,
α = the coefficient of expansion of air,
$\beta = 0{\cdot}378\frac{\phi}{\eta}$, where ϕ = mean tension of aqueous vapour and η = mean pressure of air,
θ = mean temperature of air,
$\gamma = 0{\cdot}00259 \cos 2\lambda$, where λ = latitude of place,
H_0 = the barometric pressure at the lower station,
H = the barometric pressure at the upper station.

Inserting numerical values for the British system, the equation becomes

$$Z = 60368{\cdot}6[1{\cdot}00157 + 0{\cdot}002039(\theta - 32)]\left(\frac{1}{1 - 0{\cdot}378\frac{\phi}{\eta}}\right)(1 + 0{\cdot}00259 \cos 2\lambda)\left(1 + \frac{Z + 2z}{20902950}\right)\log\frac{H_0}{H} \quad . \quad . \quad . \quad (2),$$

and the *International Tables* give the values of log A, log B, log C, log D, where

$$\log A = \log 60368{\cdot}6[1{\cdot}00157 + 0{\cdot}002037(\theta - 32)],$$
$$\log B = \text{colog}\left(1 - 0{\cdot}378\frac{\phi}{\eta}\right),$$
$$\log C = \log(1 + 0{\cdot}00259 \cos 2\lambda),$$
$$\log D = \log\left(1 + \frac{Z + 2z}{20902950}\right);$$

using which notation, it is evident that

$$\log Z = \log A + \log B + \log C + \log D + \log(\log H_0 - \log H),$$

which, for the purpose of sea-level reductions, may conveniently be written in the form

$$\log(\log H_0 - \log H) = \log Z - \log A - \log B - \log C - \log D \quad . \quad . \quad . \quad . \quad (3).$$

Considering first the right-hand member of equation (3), it is clear that for any given place log Z, log C, and log D are constants. There are thus in this member of the equation only two variable logarithms (A and B) to be subtracted from the constant (log Z − log C − log D). Now if we assume any fixed laws of relationship between θ and ϕ on the one hand, and the observed temperature and vapour tension at the upper station on the other hand; and if we assume (as it will be shown later we may justly assume) η to have a constant mean value for the purpose of calculating log B; it is obvious that this subtraction can be readily performed by a simple slide-rule suitably graduated for temperature and pressure *as observed at the upper station.*

The left-hand member of the equation (3), though it appears at first sight more difficult to deal with, can be treated equally easily. For if M and N are any two quantities comparable in magnitude with the extreme heights of the mercury column at any given place, and if c and d are any two other quantities comparable in magnitude with the extreme

corrections required to reduce the barometric height at that place to sea-level, then, the squares and higher powers of quantities such as $\frac{c}{M}$ being negligible, we may write, without sensible error,

$$\log_e \frac{M+c}{M} = \frac{c}{M},$$
$$\log_e \frac{M+d}{M} = \frac{d}{M},$$
$$\log_e \frac{N+c}{N} = \frac{c}{N},$$
$$\log_e \frac{N+d}{N} = \frac{d}{N},$$

whence

$$\log \frac{c}{d} = \log \frac{\frac{c}{M}}{\frac{d}{M}} = \log \frac{\log \frac{M+c}{M}}{\log \frac{M+d}{M}}$$
$$= \log [\log (M+c) - \log M] - \log [\log (M+d) - \log M] \quad . \quad . \quad . \quad (4),$$

an expression which will clearly not alter in value when we replace M throughout by N. Hence we have

$$\log [\log (M+c) - \log M] - \log [\log (M+d) - \log M]$$
$$= \log [\log (N+c) - \log N] - \log [\log (N+d) - \log N] \quad . \quad . \quad . \quad (5),$$

which is the condition required in order that it may be possible to obtain the corrections c and d by a simple pair of suitably placed slides, one of which bears divisions proportional to the differences between the logarithms of different values of the observed barometric height, and the other is graduated with the interval between the corrections c and d equal to

$$\log [\log (M+c) - \log M] - \log [\log (M+d) - \log M],$$

where M is *any* barometric height between the extremes observed at the station. The mean barometric reading is conveniently taken for M, but the investigation shows that the results will not vary by more than an entirely insignificant amount if any other reading between the extremes be used instead of the mean.

It will be shown later that it is possible so to locate this second pair of slides, and the first pair already mentioned, on a single rule, that by placing any given observed vapour tension (on the log B scale) against any given observed air temperature (on the log A scale), the correction to sea-level can be immediately read off against that point on the log H scale which corresponds to any given barometric reading H simultaneously observed at the station.

Thus, the slides being once made and graduated, the rule will at all times and under all conditions (excluding abnormal inversions of temperature and humidity in the air strata, in which cases no fixed method of procedure whatever can hold) give very accurately the correction to sea-level for the barometer at the station for which it is designed. And as this is done by a single setting of the rule, without the smallest calculation or reference to tables, reductions can easily be performed at the rate of two per minute. When it is added that the calculation of the scales and the construction of the rule in cardboard will not require more labour than the reduction of a score of observations by the *International Tables*, it will be apparent that the value of the rule as a time-saving machine may be

very considerable where a large number of reductions for the same barometer have to be performed.

It may be well, before describing the construction of the scales, to justify the approximations mentioned above for the graduation of the vapour-tension and correction scales by actual trial in the case of a high station with largely varying meteorological conditions, in which case the errors involved in the approximations will appear at their maxima. We will take as an example a station 2000 ft. above the sea-level, which is higher than any meteorological station yet dealt with by the author, and assume possible ranges of air temperature from 50° to 100° F., and of pressure from 27 to 29 ins. The correction to sea-level will then range approximately from 1·8 in. to 2·1 ins.

If under these extreme conditions we investigate the error produced by considering (for the purpose of the vapour-tension scale only) the barometric pressure to be constant at its mean value instead of varying between the given limits, we find the maximum uncertainty in the resulting correction to be 0·0004 in., which is about the variation which would result from an error of 0°·1 F. in the temperature, and is therefore quite negligible.

With regard to the second approximation (that of the correction scale) the uncertainty is even less significant. For if we substitute the given limits into the approximate equation (5) mentioned above, it becomes

$$\log(\log 28{\cdot}8 - \log 27) - \log(29{\cdot}1 - \log 27) = \log(\log 30{\cdot}8 - \log 29) - \log(\log 31{\cdot}1 - \log 29),$$

the two members of which work out to be 0·06466 and 0·06481, the difference indicating an uncertainty of only 1 in 900 in the range of correction deduced from the mean; and as the total range of the correction is only 0·3 in., the uncertainty in the result is only about 0·0003 in., a quantity quite negligible even in the most refined barometric measurements.

3. *Calculation of the Scales.*

The calculation of the scales is easily performed with the aid of the *International Meteorological Tables* and a book of logarithms. It is of course premised that the latitude and altitude of the station are known, and also that the usual assumptions are made with regard to the fall of temperature, pressure, and humidity with increase of altitude.

The method of calculation will be best shown by an example, and for this purpose the case of Khartoum will be taken. Khartoum is situated in latitude 15° 36′ N., and its altitude is 1233·6 ft. above sea-level. In accordance with the mean results of numerous observations in tropical countries, we may assume that an increase of altitude of 1000 ft. is accompanied by a fall in the air temperature of 3°·1 F.; hence the mean temperature of the air between Khartoum and sea-level may be taken as constantly greater than the air temperature at Khartoum itself by 1°·9 F. On similar assumptions the mean pressure of the air may be taken as 0·6 in. higher than the pressure at Khartoum itself, while the mean vapour tension may be taken as 1·07 times that observed at Khartoum.

The approximate limits of air temperature at the place are 50° and 100° F., those of pressure being 28·0 ins. and 29·2 ins., while from a

rough preliminary computation the sea-level correction may vary from 1·15 in. to 1·35 in. The vapour tension varies from 0 to 1 in. These are only rough values to indicate the extent of the scales required.

It is now necessary to fix on a unit for the scales. A convenient linear unit is 0·1 in. for each 0·001 of logarithmic difference; this gives scales sufficiently open for the correction to be easily read to 0·001 in. while the instrument is kept within a total length of 15 ins. Needless to say, the same linear unit must be adhered to for all the four scales of any one rule.

Temperature Scale.—Let t be the observed air temperature at Khartoum, θ the mean temperature of the air between the station and the sea-level. Then, as mentioned above, we shall take $\theta = t + 1°{\cdot}9$ F. It will be sufficient to fix the divisions of the scale for each 10° F. of temperature interval, proportioning the individual degrees afterwards. We then, with the aid of the *International Tables*, make the calculation as follows:—

t	=	50°	60°	70°	80°	90°	100°
θ	=	51·9	61·9	71·9	81·9	91·9	101·9
log A	=	4·79872	4·80713	4·81538	4·82347	4·83142	4·83922
differences	=	·00841	·00825	·00809	·00795	·00780	
scale-lengths (inches)	=	·841	·825	·809	·795	·780	

The space in inches between the 50° and 60° marks on the scale will thus be 0·841, and so on.

Vapour-tension Scale.—Assuming the mean pressure of the air to be constantly equal to 29·0 ins., we calculate the scale-lengths for differences of 0·5 in. of vapour tension thus:—

f = vapour tension at place	=	0	0·5	1·0
ϕ = mean vapour tension in air = $f \times 1{\cdot}07$	=	0	0·54	1·07
log B (from tables)	=	0	0·00307	0·00609
differences	=	0·00307	0·00302	
scale-lengths (inches)	=	·307	·302	

Barometer Scale.—This can be calculated to get the divisions for each 0·4 in., as follows:—

H = barometer reading	=	28·0	28·4	28·8	29·2
log H	=	1·44716	1·45332	1·45939	1·46538
differences	=	0·00616	0·00607	0·00599	
scale-lengths (inches)	=	·616	·607	·599	

Correction Scale.—This is conveniently calculated for each 0·05 in., from 1·15 in. to 1·35 in., in the following form, where H = any barometric reading, say 28·5 ins., and H_0 = H + the sea-level correction. Thus H can be assumed constant for this calculation; the same result for the correction-scale would be arrived at by taking 28 ins. or 29 ins. for H in place of 28·5 ins. It is convenient to use 6- or 7-figure logarithms for H and H_0, though 5-figure tables are sufficient in the remainder of the process.

H	=	28·50				
correction	=	1·15	1·20	1·25	1·30	1·35
H_0	=	29·65	29·70	29·75	29·80	29·85
log H_0	=	1·4720247	1·4727564	1·4734870	1·4742163	1·4749443
log H	=	1·4548449	1·4548449	1·4548449	1·4548449	1·4548449
log H_0 − log H	=	0·0171798	0·0179115	0·0186421	0·0193714	0·0200994
log (log H_0 − log H)	=	$\bar{2}$·23502	$\bar{2}$·25313	$\bar{2}$·27049	$\bar{2}$·28716	$\bar{2}$·30318
differences	=	0·01811	0·01736	0·01667	0·01602	
scale-lengths (inches)	=	1·811	1·736	1·667	1·602	

Calculation for Localising the Scales.—In order that the four scales may be placed correctly in relation to each other, in making the rule, it is necessary to calculate the coincident points for some one set of conditions. Let us suppose the barometer reading is 29·0 ins., the temperature of the air at the station 80° F., and the vapour tension 0·50 in., and calculate the correction by the logarithmic tables in the ordinary way, thus :—

$\log A = 4{\cdot}82347$	$\log Z = 3{\cdot}09017$
$\log B = 0{\cdot}00307$	
$\log C = 0{\cdot}00096$	
$\log D = 0{\cdot}00003$	
$4{\cdot}82753$	$4{\cdot}82753$
	$\log(\log H_0 - \log H) = \bar{2}{\cdot}26264$
	$\therefore \log H_0 - \log H = 0{\cdot}01831$
	$\log H = 1{\cdot}46240$
	$\log H_0 = 1{\cdot}48071$

whence $H_0 = 30{\cdot}249$ ins.
and the correction $= H_0 - H = 1{\cdot}249$ in.

The scales must therefore be so placed that when 1·249 on the correction scale is opposite 29·000 on the barometer scale, 80° on the temperature scale shall be against 0·50 on the vapour-tension scale. The only other necessary condition is that the direction in which the scales run (*i.e.* to right or left) must be considered. If the fixed part of the rule contains the temperature and barometer scales, both graduated from left to right, then the sliding portion must have the correction scale graduated in the same, and the vapour-tension scale graduated in the reverse, direction. The calculation of localisation automatically does away with the necessity for any further consideration of log Z, log C, and log D in constructing the rule.

4. *Construction of the Rule.*

The instrument is conveniently made of stout Bristol board. One piece about 15 ins. by 5 ins. is taken for the fixed scales, and another piece about 1 in. wide by 15 ins. long for the moving portion. The scales are best drawn in Indian ink after first marking out in pencil.

Fixed Portion of the Rule.—A horizontal line is drawn lengthwise down the middle of the card. Starting about 1½ in. from the left-hand edge, this line is graduated in divisions of 10° each from the scale-lengths computed; thus from 50° to 60° will be 0·841 in., from 60° to 70° will be 0·825 in., and so on. The single degrees can readily be put in by sub-division.

The barometer scale will conveniently commence about 1½ in. to the right of the 100° division, on the same line, and will run from left to right like the temperature scale. The data already calculated give the intervals between the 28·4 and 28·8 marks, and so on; the single tenths of an inch can then be filled in by sub-division of the larger spaces.

Sliding Portion of the Rule.—The correction scale can be at once put on the upper edge of the strip of card, beginning conveniently about 7 ins. from the left-hand end, and the graduations running from left to right. As in the case of the fixed scales, the computed data give the large divisions, and the smaller ones can be made by sub-division.

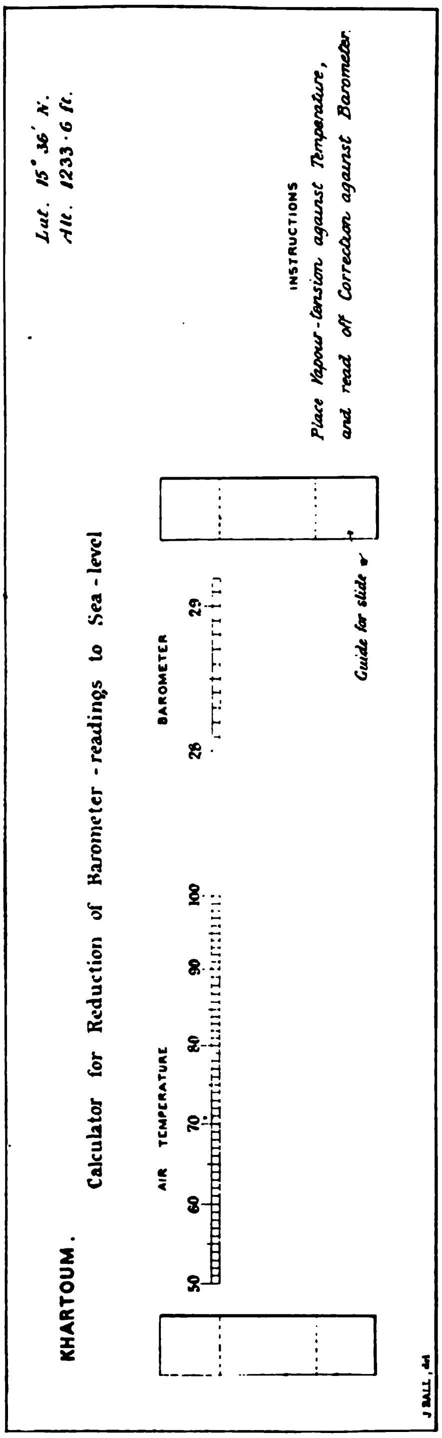


Fig. 1. Fixed part of rule

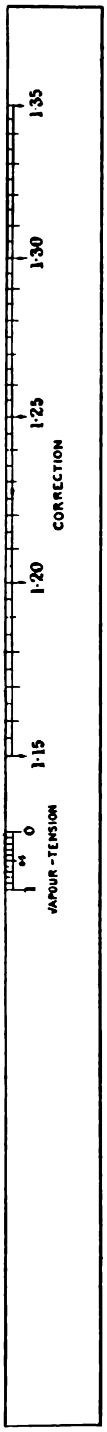


Fig. 2. Slide.

The sliding portion must also bear the vapour-tension scale, whose position is, however, governed by the localising calculation above made. Placing 1·249 on the correction scale against 29·00 on the barometer scale, we can at once mark off, against 80° on the temperature scale, the division corresponding to 0·5 in. of observed vapour tension. Now the vapour-tension scale must, as remarked above, run in the opposite direction to the others; we therefore place the 0·0 mark 0·307 in. to the *right* of the 0·5 mark, and the 1·0 division 0·302 in. to the left. The remaining tenths of an inch can now be filled in by sub-division, and the rule is complete.

If now any given vapour tension be set against any given air temperature, both being observed at Khartoum, the correction to sea-level can be at once read off against the simultaneously observed barometer reading. It is convenient to gum a pair of cardboard guides for the slide near the ends of the fixed portion of the rule. Drawings of the fixed portion and the slide are shown separately in Figs. 1 and 2.

5. *Speed of Working.*

In order to test the economy of time resulting from the use of the rule under ordinary working conditions, sea-level corrections were taken out for three sets of conditions chosen at random, the reductions being performed in each case by the rule and by an experienced computer using the logarithmic tables. The results are shown below:—

Air Temperature.	Vapour Tension.	Barometer Reading.	Sea-level Correction.		Time Occupied.	
			By Rule.	By Tables.	By Rule.	By Tables.
°	in.	in.	in.	in.		
65	0·30	28·10	1·248	1·248	80 seconds	16 minutes
90	0·80	28·70	1·208	1·208		
75	0·60	29·10	1·263	1·263		

The rule thus yields results of equal precision with those of the tables; but while the reductions with the rule occupied less than a minute and a half, those by the logarithmic tables consumed 16 minutes.

DISCUSSION.

The CHAIRMAN (Capt. D. WILSON-BARKER) thought that the thanks of the Society should be given to Dr. Ball for his paper, as all those who had much to do with making a considerable number of barometer reductions would appreciate any help that would tend to lighten their labours and difficulties.

Mr. W. MARRIOTT said that he was glad to see the slide rule which Dr. Ball had designed for reducing the reading of the barometer to sea level. Anything that tended to lessen the time and labour in the reduction of the observations was always welcome. He (Mr. Marriott) gathered that the time occupied in reducing an observation by Dr. Ball's slide rule was half a minute, but he himself had brought before the Society in 1875 a Table which combined three corrections,

viz. index error, temperature, and altitude, by the use of which a greater saving of time was effected than by using Dr. Ball's slide rule. This combined Table was used by the Society's observers, and was also set out in the *Hints to Meteorological Observers.* When the Royal Meteorological Society started their Second Order stations in 1875, he found great difficulty in getting simple tables for reducing the barometer readings. The various treatises on Meteorology only gave the corrections for two sea-level pressures, viz. 27 ins. and 30 ins.; it was consequently necessary to go through some calculations before the correction for any intermediate reading could be obtained. He subsequently calculated and printed in the *Hints* the corrections for pressures at 28 ins., 29 ins., and 31 ins. from 10 to 1000 feet above sea level at temperatures from 20° to 80°. As a change of 0·6 in. in the pressure produces the same amount of variation in the correction for altitude as an alteration of 10° in the temperature of the air, it was possible by taking the mean height of the barometer to combine the correction for temperature with that for altitude, and when the index error is the same throughout the scale, as in the Fortin barometer, it could also be included. By the use of such a combined Table the three corrections could be made by one operation, and the liability to error thereby greatly reduced. The time occupied in applying these three corrections was rather less than that taken by Dr. Ball in applying one correction only.

[Dr. J. Ball, in a letter to the Secretary subsequently, said that he desired to point out that his slide-rule method was not designed to compete with that of Mr. Marriott's tables in the ordinary cases, where only a moderate degree of accuracy was required. In such cases no method could possibly be simpler or more convenient in use than the tables given in *Hints to Meteorological Observers.* But in north-east Africa the problem of sea-level correction presented itself in a somewhat peculiar aspect. The ordinary non-periodic variations of pressure there were of a much smaller order than those in European countries, and consequently in the reduction of readings it was necessary to go to a very high degree of precision, in order to compare them properly. When the greatest possible precision was required in the reduced readings, the tables of Mr. Marriott were insufficient. The assumption that the change produced in the correction by a rise of 0·6 in. in the barometer was equal to that produced by a fall of 10° in the air-temperature, though no doubt a very close approximation in most cases, was not strictly accurate. It was further essential, for great accuracy, to take account of the varying amount of aqueous vapour in the air, and of the effect of variation of gravity on the weight of the air-column considered, both of which, being small effects, were neglected in the tables of Mr. Marriott. As an instance, he had calculated the correction to sea-level for a barometer-reading of 29 ins. at Merowe (lat. 18° 29′, altitude 876 feet), the air-temperature and vapour-tension at the station being respectively 50° and 0·4 in. The tables of Mr. Marriott gave the value as 0·919 in., while rigorous calculation by the logarithmic tables, with the usual assumptions of temperature-gradient, etc., gave 0·938 in.; and this latter value of course agreed with that found by the slide-rule. He thought Mr. Marriott would admit that in cases such as this, true variations of pressure might, if very small, be entirely masked by the small errors inherent in the method of formation of his tables; and in order to obtain a sufficiently accurate reduction in such cases, it had hitherto been necessary to employ either the method of M. Angot, or the logarithmic method, both of which were embodied in the *International Tables.* The new slide-rule was founded on the logarithmic method, and while immensely more rapid in use than the *International Tables*, it gave results of equal accuracy with them. Thus, although his rule was not designed to replace the useful tables of Mr. Marriott in ordinary cases, he trusted that it would find a field of considerable usefulness in cases where the utmost precision was required in barometric reductions to sea-level.]

Rainfall in Fiji, 1904.

The following is the rainfall taken at Delanasau, Bua, Fiji, in 1904. Lat. 16°·38′ S., long. 178°·37′ E.; height above sea level, 71 ft.; distance from sea, 1 mile:—

1904.	Rainfall.	No. of Rainy Days.	Max. Fall in 1 Day.
	ins.		ins.
January	22·52	28	4·92
February	7·25	21	1·68
March	14·13	20	3·31
April	10·10	19	2·19
May	3·40	11	0·67
June	1·13	9	0·37
July	0·34	4	0·28
August	3·03	8	1.06
September	4·01	11	1·40
October	2·41	7	1·63
November	4·48	5	2.26
December	10·76	21	3·39
Total	83·56	164	4·92

The average fall in 34 years was 93·49 ins. The greatest yearly fall was 159·51 ins. in 1871, and the least 52·55 ins. in 1903. The year 1877 was our worst season of drought here, and a year of extraordinary fall elsewhere in the group. In the first three months of that year there fell here 62·38 ins., in the subsequent nine months only 18·15 ins., and in the five months ending December 31 only 5·29 ins. fell. In contrast to this I may mention the phenomenal rainfall in that year, 1877, in South Taviuni in particular. Mr. James Newall, living at Qara Walu near Vuna, two and a-half miles from the sea, and 594 feet above sea level, sent me the following particulars of the rainfall:—In 1876 there fell there 243·07 ins. on 236 days; and in 1877, 251·57 ins. on 228 days. Constant, strong Southerly winds caused all this, floods and droughts in the two instances respectively, Vuna being exposed to the wind off the sea, while here the same Southerly wind had to cross Vanua Levu, and so became dry.

In the sun's rays I registered 172° on December 24, 1877, the extreme limits of the instrument,—a black bulb thermometer,—and on December 24, 1904, I observed 156°·5. In December 1877 the salt water in a tidal creek here registered 97° five feet below the surface. Yet, in contrast to all this, the lowest temperature in the shade at night occured here on September 14, 1877, namely 56°·6; the maximum in the shade, also a record, 98·7, occurred on January 6, 1878. Yet one more record for that year was the hygrometer readings on November 18, 1877, viz. dry bulb, 93°·6, wet bulb, 74°·8; difference 18°·8; the percentage of moisture in the air being only 37.—R. L. Holmes, F.R.Met.Soc.

NORMAL ELECTRICAL PHENOMENA OF THE ATMOSPHERE.

By GEORGE C. SIMPSON, B.Sc., F.R.Met.Soc.

[Read June 21, 1905.]

In no branch of physics has the discovery of "ions," "electrons," and "radio-activity," produced a greater revolution than in that devoted to atmospheric electricity. During the last few years our knowledge and theories of atmospheric electricity have been so completely changed, and the change has been so rapidly made, that unless one has devoted much time and study to the literature of the subject, it has become very difficult, and almost impossible, to realise the position now attained. It is with the idea of stating as shortly as possible the chief line along which investigations have been made, the conclusions arrived at, and the problems still awaiting solution, that this paper has been undertaken.

It is well known that if an electroscope is connected to a conducting body insulated in the open atmosphere the leaves slowly diverge, showing that the body takes up an electrical potential differing from that of the earth. This difference of potential is the greater the higher the body is above the earth—it being supposed that there are no building, trees, etc., near. Thus we speak of a difference of potential, or a potential gradient in the atmosphere.

This observation was the starting point of the study of atmospheric electricity; but before going on to later developments it will be as well to define at once the special meanings in which terms to be used later in the paper are to be understood.

Definitions.

The *potential gradient* means the difference of electrical potential between two points one metre apart vertically, the ground surrounding them being supposed to be a level horizontal plane. The value of this gradient when measured near the ground depends entirely on the charge on the surface of the earth, a potential gradient of 100 volts per metre representing an electrical charge of 10^{-13} coulombs per square centimetre of surface. On account of the direct relation between the charge on the surface and the potential gradient the two will often be spoken of as the same variable.

An *ion* is any minute material particle which carries an electrical charge. Generally an ion is an atom or a molecule of atmospheric gas carrying an elemental charge of electricity. Two ions, one positive and one negative, are produced by the breaking up of a neutral molecule into two charged atoms or two charged molecules of smaller dimensions.

Ionization is the process of the formation of ions by the splitting up of neutral molecules.

The active agent which produces ionization is called the *ionizer*.

The *state of ionization* of a gas is defined by the number of ions in a given volume of gas.

Potential Gradient.

It is now generally accepted that the normal potential gradient over the whole globe is positive, that is, the whole surface of the earth, except regions of disturbance, has a charge of negative electricity. This charge is not constant in amount, but undergoes considerable yearly and daily variations.[1] [The references will be found at the end of the paper.]

The yearly variation is a simple one, and appears to be the same for all places at which observations have yet been made. The charge on the ground begins to increase rapidly in the autumn; by midwinter or in the following months it has reached a maximum, from which it rapidly descends during the first spring month to remain constant at its lowest value during the summer.

There are two distinct types of daily variation. The first type consists of a single period having only one maximum and one minimum—the maximum falling in the evening, and the minimum about 4 a.m. The second type has two maxima and two minima—the former occurring at about 8 a.m. and 8 p.m., and the minima about 4 a.m. and mid-day.

Dissipation.

Until 1887 potential gradient was the only factor of atmospheric electricity recognised and measured. In that year Linss[2] showed that another electrical property of atmospheric air is its ability to discharge a charged insulated body. For some time it was thought that this discharging or dissipation of electricity from an insulated body was either the result of defective insulation, and so only apparent, or the effect of the dust in the atmosphere; it was strongly held that pure air is an absolutely perfect non-conductor of electricity. But in 1900 and 1901 Elster and Geitel[3] in Germany, and C. T. R. Wilson[4] in England published researches which showed that dust free air has the power to discharge perfectly insulated bodies. These physicists came to the conclusion that pure air is not an insulator, but that it always contains a number of ions which give to it the power of conducting electricity in a manner similar to that of an electrolyte. Until this discovery had been made there had been little difficulty in explaining the earth's permanent negative charge; it could be regarded as a residual charge left at the formation of the earth which had been kept on the surface by the non-conducting atmosphere surrounding it.[5] This theory obviously had to be relinquished when the atmosphere was found to be a comparatively good conductor; for such a residual charge on the earth's surface would be rapidly dissipated into the higher regions of the atmosphere. This was a most important conclusion, and led Elster and Geitel, to follow up their discovery with great vigour. Not only Elster and Geitel, but many other German scientists have turned to this subject, in particular Ebert, Gockel, and Zölss. It is impossible here to go through the work of each of these, or to ascribe to each his just share of the progress made, we must be content with the final results to which all have contributed.

One of the earliest results arrived at was that the two kinds of electricity are not dissipated at the same rate. In the lower atmosphere negative electricity is dissipated more rapidly than positive, the reason

being that there are more positive than negative ions in the air near the surface, which is a consequence of the former being attracted downwards, and the latter being repelled upwards by the negative charge on the earth. It was found as the result of a large number of measurements that the mean rate of dissipation of negative electricity is between 10 and 20 per cent greater than that of positive.

Great attention has been given to finding the influence of the different meteorological conditions of the atmosphere on the rate at which a charged body loses its charge, the idea being to investigate the rate at which the earth loses its charge at different times of the year and under different meteorological conditions. Shortly stated the results of the work are the following:—

Dissipation and Meteorological Conditions.[6]

1. The effect of increased *wind strength* is to increase the rate of dissipation of both kinds of electricity.

2. *Temperature* has a pronounced influence, the lower the temperature the less the dissipation.

3. The effect of *relative humidity* is complicated. When the humidity is less than about 60 per cent it has little effect on the dissipation; as the humidity still further increases the dissipation begins to be reduced, but the rate at which positive electricity is dissipated is reduced much faster than the rate of negative dissipation, the consequence being that the ratio of negative to positive dissipation becomes greater as the humidity increases.

4. The *clearness of the air* also affects the dissipation. Other conditions remaining the same, the dissipation is greater the clearer the air. On those dull, oppressive, hazy days which occur so often in mid-summer the dissipation becomes exceedingly small, while a clear, bright day in mid-winter is often accompanied by comparatively great dissipation.

These relations must have a physical explanation, and we will now devote some time to the consideration of possible explanations.

As no dissipation would be possible without ions, and no ions can be produced without the action of some ionizer possessing the necessary energy, we must first find what ionizer is at work in the atmosphere.

Possible Atmospheric Ionizers.

Laboratory experiments have shown five means by which air can be ionized: (1) Ultra-violet light; (2) High temperature; (3) Chemical processes; (4) X-rays; (5) Becquerel rays.

Every one of these has been pressed into service to explain the natural ionization of the air by one writer or another. We will now examine the pros and cons for each taken in turn.

1. *Ultra-violet Light.*—Lenard[7] showed that ultra-violet light has the power of ionizing air. There can be no doubt that as the sun emits ultra-violet rays the air must to some extent be ionized by them. Nevertheless it is quite impossible for any appreciable amount of the ionization of the lower atmosphere to be due to this cause, for all the rays which have ionizing powers will be absorbed in the upper atmosphere

long before they come anywhere near the layer of air which we investigate with our instruments.

2. *Temperature.*—It is well known that the gas in flames is ionized. It is supposed that this ionization is due to the breaking up of neutral molecules into ions, either by their excessive vibration or by collisions caused by their high temperature. Thus one would expect the ionization of a gas to be a function of its temperature, for high velocities occur at all temperatures, only increasing in frequency as the temperature rises. Most careful experiments have been made to investigate this point, but all the results have been negative.[8] So far as can be detected there is no change in the natural ionization of a gas, as its temperature rises until a very high temperature (over 850° F.) is reached, when a sudden ionization of the gas takes place.* Temperature then cannot contribute anything to the ionizing forces at work in the atmosphere.

3. *Chemical Processes.*—It is strange, in view of the results of the experiments described in the last paragraph, that the ionization of the atmosphere should be found to be greater with high than low temperatures. In order to explain this Gockel[9] has suggested a chemical ionizer. It has long been known that the production of ozone is accompanied by ionization; thus the production of ozone in the atmosphere might be expected to be accompanied by ionization also. The natural production of ozone is very dependent on temperature, high temperatures facilitating the production, and low temperatures retarding it. The direction of the change with temperature is right; but many more observations[10] of the relation between ozone and atmospheric ionization are necessary before such a theory could be seriously held.

4. *X-Rays.*—It has long been known that X-rays have the power of ionizing a gas, and that they are absorbed by dense materials such as lead, mercury, etc. M'Clennan[11] has shown that when a mass of gas is surrounded by thick walls of lead its natural ionization is reduced. This seems to indicate that the lead cuts off some radiation, having the nature of very penetrating X-rays. Whether these rays have a terrestrial or a cosmical origin cannot be decided, for they appear to traverse the atmosphere in all directions. They were found to account for 20 per cent of the natural ionization of a gas enclosed in an experimental vessel.† Here then is the first trace of an ionizer active in the lower atmosphere.

5. *Becquerel Rays.*—These are the rays given off by radio-active bodies, and they are very efficient ionizers. Under this heading I wish only to include the α and β rays as defined by Rutherford, the γ rays belonging properly to the last paragraph.

Three sources of Becquerel rays with power to ionize the atmosphere have been suggested: (*a*) the sun, (*b*) radio-active substances in the earth itself, and (*c*) radio-active emanations in the atmosphere.

(*a*) *The Sun.*—The emission of Becquerel rays by the sun forms a very interesting subject for conjecture. At present we have no direct experi-

* Even the ionization which sets in at 850° F. is ascribed to the effects of the hot walls of the vessel containing the gas, and not to the direct action of temperature on the gas itself.

† It is not clear whether this radiation would produce the same ionization if the air were not enclosed, it being supposed that a secondary radiation is caused by the rays striking the walls of the vessel.

mental evidence of such rays; but if such rays exist a number of phenomena which have been riddles to geophysicists for a long time receive their explanation. Assuming a discharge of β rays from the sun in all directions, Strφmer[12] has just shown by a clever piece of mathematical work that the earth's magnetic field will cause these rays to enter our atmosphere in two rings, one circumscribing each pole. The two theoretical regions correspond closely with the two regions of the earth in which the aurora is visible. This work gives great support to Birkeland's theory of the aurora. According to Birkeland[13] the sun does emit β rays, and these reach the atmosphere in the specified rings. Where the rays enter the atmosphere they ionize the air, light being produced in a similar way to the glow in a vacuum tube.

If the sun does send out Becquerel rays, it is more than likely that they are not emitted uniformly in all directions; but that a great emission accompanies those explosions which give rise to sun-spots and prominences. Thus we shall have bundles of rays shot out into space; it may be that such bundles of rays passing near to the earth cause magnetic storms, and when such a bundle passes near enough for more or less of the rays to enter the earth's atmosphere we have a magnetic storm accompanied by a brilliant aurora.

If this theory is correct, it is not likely that we should be able to recognise the rays near the earth's surface,[14] for it must be remembered that the absorbing power of the atmosphere for such rays is equivalent to that of a 30-inch layer of mercury, and no α or β rays yet discovered could pierce such a mass of mercury. Thus we see that we must leave Becquerel rays having their source in the sun out of account when explaining the ionization of the lower atmosphere.

(*b*) Turning now to the Becquerel rays having their source in the radio-active constituents of the earth's crust, we know, from the work of Elster, Geitel, Strutt, and others,[15] that such substances are present in at least minute quantities in practically all mineral substances. The rays emitted by these substances must to a greater or less extent ionize the lower regions of the atmosphere. This, then, is the second possible ionizer.

(*c*) The final source of Becquerel rays mentioned was the radio-active emanation in the atmosphere. As is well known, radio-active bodies continually give off a substance in many ways very similar to a gas, and to which the name emanation has been given. Emanation has the power of ionizing a gas, and the peculiar property of not being a permanent form of matter, so that it apparently slowly disappears from a gas containing it. Elster and Geitel[16] discovered in 1902 that there is always a varying amount of radio-active emanation in the atmosphere. There can be little doubt that part, at least, of the ionization of the air is due to this cause.

Thus we see that there are at least three ionizers at work in the lower atmosphere, viz. an X-ray-like radiation, radio-active matter in the ground, and radio-active emanation acting in the atmosphere, and it remains for us to see how these are affected by meteorological conditions.

Ionizers and Meteorological Conditions.

It has been already stated that the X-ray-like radiation is very penetrating; that being so, it is difficult to see how any change in the

meteorological conditions of the air could influence it. The slight increase of density, due to changes of temperature or pressure, could only affect a radiation capable of penetrating two or three inches of lead to a very slight degree; thus we can only make a very small mistake by assuming that this ionizer is unaffected by meteorological conditions.[17]

Similar considerations apply also to the radiation from the radio-active substances of the earth. The amount of radio-active matter mixed up with the soil is so very small that the amount in the surface layer to a depth of say 5 inches could only very slightly ionize the air above. Thus if *an appreciable amount* of ionization is due to the radio-activity of the soil, it must be caused by the radiation emitted by soil at a greater depth than 5 inches. That being so, the effective radiation must have penetrated more than 5 inches of soil, and so must be considered a penetrating radiation; thus it comes under the class of radiations just discussed, on which meteorological conditions have been shown to have little effect.

We are now reduced to one source of radiation which can be affected by meteorological conditions, viz. that due to the radio-active emanation in the atmosphere itself, and this must be considered at greater length. As stated above, Elster and Geitel were the first (in 1902) to detect and measure the radio-active emanation in the atmosphere; since then a number of physicists have worked at the subject.[18] The amount of emanation in the atmosphere has proved to be a very varying quantity and to be largely dependent on meteorological conditions. From recent work it appears that the relation between atmospheric radio-activity and meteorological conditions can be expressed as follows: The amount of emanation in the lower regions of the atmosphere is increased by all those meteorological conditions which tend to keep the air stagnant over the earth's surface. The meteorological conditions which either cause or often accompany stagnant air are calm, low temperature, and high relative humidity; while on the contrary high winds, high temperature, and low humidity generally accompany the mixing of large masses of air. This all agrees with the observed facts that the atmospheric radio-activity increases with falling temperature, rising humidity, and increasing wind strength. The explanation of this relation is simple. As already stated, the soil of the ground has been found to contain almost universally radio-active substances. These substances are continually giving off an emanation which, having the properties of a gas, is always diffusing into the atmosphere above. When the air is stagnant the emanation can only slowly pass out of the lower atmosphere, so that the latter under suitable circumstances may become very highly charged with emanation. Thus, at least, one of the ionizing forces is very dependent on meteorological conditions; and the question at once arises, Does this explain the dependence of the dissipation on meteorological conditions? By referring back, it will at once be seen that each of the meteorological conditions which tend to produce high values of the radio-activity, without exception, accompany low values of the dissipation. This is exactly the reverse of what would be expected from the ionizing properties of emanation, if the emanation were the chief ionizing factor of the atmosphere.

Having now examined all the known ionizing forces in action in the atmosphere, and having found all uninfluenced or influenced in the wrong

direction by meteorological conditions, we must seek some other cause to account for the relation between dissipation and meteorological factors. At present we have only examined one of the factors which determine the state of ionization of the atmosphere. There is still another, namely, the rate at which ions recombine to form neutral molecules. This we will now consider.

Rate of Recombination of Ions and Meteorological Conditions.

It has been shown by laboratory experiments that when ions are brought into contact with matter they attach themselves to it, and so lose their properties as ions. If the air enclosed in a room is kept in rapid motion by means of a fan, it will be found that its natural ionization is quickly reduced to a minimum, owing to the walls absorbing all the ions from the air driven against them.[19] Any material particles, such as those of dust, fog, or smoke, suspended in the air, act in exactly the same way. Thus when the atmosphere, through any cause, becomes filled with minute material particles, the ionization falls very rapidly. A hazy day is accompanied by low ionization on account of the minute particles which the haze indicates. The low ionization and dissipation found with low temperatures is probably due to a similar cause. As the temperature falls below 32° F. the air may become more or less filled with particles of ice which absorb the ions. These are the particles which, becoming larger as the temperature falls, finally fill the air with the palpable ice crystals to which solar and lunar halos are due. In such ice crystal-laden air I have met as low values of ionization and dissipation as are found in thick fog.

The rate of recombination of ions also appears to be greatly affected by relative humidity, at least with humidities near the saturation point. This stands, no doubt, in some relation to the fact discovered by C. T. R. Wilson,[20] that ions form nuclei on which water vapour deposits itself when dust-free air becomes supersaturated. The fact that negative ions are more affected by humidity than positive ions also points in the same direction; but the exact mechanism is difficult to see, for Wilson showed that a definite supersaturation must take place before water is visibly deposited on ions. Perhaps there is a tendency for ions to attract water molecules before saturation takes place, and that in nearly saturated air the ions are already laden with water molecules to a large extent.

Returning now to the observed relations between meteorological factors and dissipation we find that some have received their explanation and others not.

1. *Wind Strength.*—The dissipation must obviously be greater in a wind than in a calm, for the wind brings so much more air into contact with the charged body.

2. *Temperature.*—The effect of temperature has not been explained. Some effect of low temperatures may be due to minute ice crystals in the air; but this does not explain the relation at higher temperatures.

3 and 4. *Relative Humidity* and *Clearness of the Air.*—The relation between these factors and dissipation is no doubt due to the effect they have upon the rate of recombination of the ions produced by the active ionizer; but the action of the relative humidity is not clearly understood.

Dissipation and Potential Gradient.

Having now investigated the causes and variation of dissipation itself, we must turn to the problem from which we started. What is the effect of continual dissipation upon the charge on the earth's surface?

Linss' first series of measurements of the dissipation showed a pronounced yearly period, the dissipation being considerably greater in the summer than the winter. That this should be so might be expected from the different meteorological conditions of the summer and winter; but that the meteorological changes are sufficient to account for the whole yearly variations of the dissipation is very doubtful. Attention was at once drawn to the fact that the yearly variation of dissipation is nearly the exact reverse of the yearly variation of the potential gradient.

Further measurements have shown that at all seasons of the year there is a marked connection between potential gradient and dissipation;[21] high values of the potential gradient nearly always accompany low values of the dissipation. This relation receives a simple explanation if we assume that the earth is every second receiving a definite quantity of negative electricity. Imagine this to be the case, then the earth would gradually charge up until the same amount of electricity is being dissipated as received. If the amount of dissipation were changed, from no matter what cause, the charge on the surface would increase or decrease until the balance is again reached. We see then that the observed phenomena would be explained if the earth were constantly in receipt of negative electricity. Whence and how could this electricity come? is the chief problem of atmospheric electricity, beside which all others are of only secondary importance. The theories[22] advanced to explain this problem have been very numerous. Some have never been taken seriously by any but their authors; while others have, for a time at least, been accepted by a large proportion of physicists.

It is not my intention to discuss these theories in any detail; but two or three must be briefly mentioned on account of their importance.

The first must certainly be that of Elster and Geitel;[23] for this theory was considered for two or three years to have solved the riddle. These two physicists explained the phenomena by the following considerations:—It is an established fact that the molecular motions of negative and positive ions in free air are different, the negative ions moving the faster. Thus if an insulated body is exposed to air, containing an equal number of positive and negative ions, more negative than positive ones must strike the body in a given time. As a consequence the body will receive a negative charge, which will go on increasing until such an electrical field is set up about it, that the electrical forces accelerating the positive and retarding the negative ions will cause an equal number of positive and negative ions to strike the body in a given time. The earth being surrounded on all sides by its envelope of air may be considered to be such an insulated body, and the normal charge on its surface to be obtained in this way. As stated above, this theory was generally accepted for some time; but it has recently been shown[24] that it is based on a wrong conception of the motion of ions, and that in-

sulated bodies do not become charged as supposed when exposed to ionized air. Elster and Geitel have lately expressed doubt as to the sufficiency of their theory.[25]

Another theory, and one which is at present receiving strong support from German physicists, has been advanced by Prof. Ebert of Munich.[26] The theory is based on an observation made by Zeleny, who found that when ionized air is passed through a narrow tube, more negative than positive ions are given to the wall, so that if any ions at all escape from the tube there will be an excess of positive. The corresponding negative ions will have been left in the tube which they will have charged. In a most ingenious way Ebert has applied this to the problem of the earth's normal charge. He says: We know that air drawn from the ground is highly laden with radio-active emanation. This emanation when in the ground must ionize the air contained in the interstices of the soil. Now suppose that the barometer falls. The pressure above the ground is reduced, therefore air will stream out of the ground; but in doing so it has to find its way through chinks and small passages in the soil, which is similar to the process described by Zeleny. Thus the air which escapes will bring out of the ground more positive than negative ions, the negative ions which remain behind going to supply the loss of the normal charge from the surface. Such a simple explanation of so difficult a problem naturally caused many physicists to receive it with pleasure, and many observers have published observations which appear to support the theory. If the theory is correct, two things might be expected to happen: (1) The amount of emanation in the atmosphere to be greater with a falling than a rising barometer; and (2) the ratio of positive to negative ions in the atmosphere to be greater under similar barometric conditions.

The first of these is an undoubted fact, the knowledge of which, no doubt, led Ebert to the formation of his theory; but the latter, the more important, is far from being proved. Observations have been published showing the looked for effect,[27] and others showing the exact opposite.[28] I would like to take this opportunity of giving the results of my own observations bearing on this point. From the results of my year's work in Lapland, I have picked out the measurements of the ionization and dissipation taken on days during which the barometer was rising or falling continuously, the change of pressure not being less than 1 mm. in twelve hours. The results are as follows:—The mean positive and negative ionizations for days, with rising barometer, were ·40 and ·34 electro-static units of free electricity in a cubic metre of air respectively. With falling barometer the corresponding numbers were ·40 and ·34. Thus no variation can be detected. The dissipation of negative and positive electricity for days with rising barometer were 3·88 per cent and 3·36 per cent, the ratio being 1·15; with falling barometer the numbers were 3·75 per cent and 3·29 per cent, $q = 1{\cdot}14$. Here there is a slight difference; but the difference is in the opposite direction to that required by Ebert's theory.

Theoretically the theory is open to very serious objections;[29] these it is impossible to go into here, one only will be dealt with. By a calculation in which assumptions ridiculously favourable to the theory are used, it can be shown that in order to separate enough electricity to supply

the deficit caused by dissipation, the barometer must fall on the average 17 mm. (·67 inch) in every 24 hours. Such a motion of the barometer is, of course, not in accordance with observation. Unless some alteration is made in the theory it is doubtful if it can continue to hold its present favoured position much longer.

C. T. R. Wilson[30] has sketched another conceivable method by which negative electricity could be conveyed from the atmosphere to the earth. As already mentioned, under certain conditions of absence of dust and supersaturation aqueous vapour will be deposited upon the negative ions of the atmosphere. Deposition started in this way will continue until drops large enough to fall as rain are formed. Rain having such an origin will be charged with negative electricity which it will give to the earth on arriving there. Wilson thinks that part of the earth's negative charge might be supplied in this way, but expressly states that the normal charge could not be entirely maintained by it.

It will be seen from all that has been said that the discovery of ions, electrons, radio-activity, etc., instead of leading to a solution of the chief problem of atmospheric electricity, has apparently made the difficulties to be explained still more formidable. A solution of the problems of atmospheric electricity can only be expected from the results of extended measurements in the atmosphere itself, and from laboratory experiments directed towards the problem. It is to be hoped that this subject will be much further pursued in the future than it has been here in England in the past.

This paper has only dealt with the normal condition of atmospheric electricity. I have found it quite impossible in the time at my disposal to treat of the abnormal conditions which give rise to the aurora, lightning, and St. Elmo's fire. Nevertheless, before concluding I would like merely to mention the relation existing between these phenomena and the normal conditions we have been discussing.

It is more than doubtful if there is any connection at all between the normal conditions of atmospheric electricity and the aurora; for although travellers in northern regions have described phenomena connecting the aurora with the potential gradient near the earth's surface, I have been unable during a year spent near the region of maximum aurora, and using the best instruments now at our disposal, to trace the slightest connection between the phenomena of the aurora and the electrical conditions of the lower atmosphere.[31]

Lightning is certainly the result of electricity in the atmosphere; but it is doubtful if it has any connection with the phenomena which we have been considering. There can be no doubt that the two are the results of entirely different causes, and that the electrical tension which gives rise to the lightning flash is not simply an abnormal increase in the earth's normal electrical field. There is perhaps still as much difference of opinion as to the cause of the electrical phenomena accompanying thunderstorms as there is to the cause of the normal electrical conditions. All possible and impossible causes, from frictional to cosmical electricity, have been assigned; but perhaps the one most generally accepted is that due to C. T. R. Wilson, and based on his discovery to which we have already referred several times. The

method by which the electricity is separated according to this theory is very complicated, but depends on the greater facility with which aqueous vapour is deposited on negative than positive ions. The theory has been very clearly sketched by Wilson[32] and Gerdien[33] to whom reference must be made for the actual details.

St. Elmo's fires are the results of conditions intermediate between those which give rise to thunder and lightning and those of the normal state. The whole thing is simply a brush discharge taking place from all points exposed to the atmosphere. The discharge is the consequence of a potential gradient much greater than the normal one, but too small, or too local, to give rise to a lightning flash.

Ball lightning and ignis fatuus are two electrical phenomena which can only be mentioned; for although they are well-authenticated natural phenomena, we have as yet not the slightest clue to either their origin or cause.

REFERENCES.

1. (a) A. B. Chaveau, *Étude de la variation diurne de l'électricité atmosphérique.* Paris, 1902. Gauthier-Villars.
   (b) Hann, *Lehrbuch der Meteorologie*, p. 715 *et seq.*
   (c) Exner, *Wiener Ber.* **9**, p. 371. 1901.
2. Linss, *Met. Zeit.* p. 345. 1887.
3. Elster and Geitel, *Drudes Ann.* **2**, p. 425. 1900.
4. C. T. R. Wilson, *Proc. Roy. Soc.* **68**, p. 151. 1901.
5. Exner, *Wiener Ber.* **93** (1886), **96** (1887), **97** (1888).
6. (a) Elster and Geitel, *Terr. Mag. and Atm. Elect.* **4**, p. 213. 1899.
   (b) ,, ,, *Phys. Zeit.* **1**, p. 245. 1900.
   (c) Czermak, *Phys. Zeit.* **4**, p. 270. 1903.
   (d) Zölss, *Phys. Zeit.* **5**, p. 106. 1904.
   (e) Gockel, *Phys. Zeit.* **5**, p. 257. 1904.
   (f) Conrad, *Met. Zeit.* p. 173. 1905.
   (g) Mazelle, *Met. Zeit.* p. 179. 1905.
   (h) Simpson, *Phil. Trans.* [part not yet issued].
7. Lenard, *Drudes Ann.* ii. p. 486; iii. p. 298. 1900.
8. (a) Mache, *Wiener Ber.* **9**, ii.a, p. 1302. 1901.
   (b) Patterson, *Phil. Mag.* **6**, 6, p. 231. 1903.
9. Gockel, *Phys. Zeit.* **5**, p. 257. 1904.
10. Conrad and Topolansky, *Phys. Zeit.* **5**, p. 794. 1904.
11. M'Clennan, *American Physical Soc.*, Dec. 1902.
12. C. Strømer, *Sur le mouvement d'un point matériel portant une charge d'électricité sous l'action d'un aimant élémentaire.* Christiania, 1904. 32 pp., 1 chart.
13. Birkeland, *Archives des Sciences physiques et naturelles*, 1901. Sér. 4, vol. **12**, pp. 565-586; or see *Met. Zeit.* **19**, p. 528. 1902.
14. Strutt, *Nature*, **68**, p. 573. 1903.
15. (a) Elster and Geitel, *Phys. Zeit.* **3**, p. 574. 1902.
    (b) ,, ,, ,, ,, **4**, p. 522. 1903.
    (c) ,, ,, ,, ,, **5**, p. 13. 1904.
    (d) ,, ,, ,, ,, **5**, p. 321. 1904.
    (e) Ebert and Ewers, ,, ,, **4**, p. 162. 1902.
    (f) Gockel, *Phys. Zeit.* **5**, p. 594. 1904.
    (g) Strutt, *Proc. Roy. Soc.* **73**, p. 192; *Phil. Mag.* **6**, 8, p. 618. 1904.
16. (a) Elster and Geitel, *Phys. Zeit.* **3**, p. 76. 1902.
    (b) ,, ,, ,, ,, **3**, p. 305. 1902.
17. Jaffé, *Phil. Mag.* **6**, 8, p. 556. 1904.
18. (a) Elster and Geitel, *Phys. Zeit.* **3**, p. 305. 1902.
    (b) ,, ,, ,, ,, **4**, p. 526. 1903.
    (c) ,, ,, ,, ,, **5**, p. 11. 1904.
    (d) Saake, *Phys. Zeit.* **4**, p. 627. 1903.
    (e) Gockel, *Phys. Zeit.* **5**, p. 591. 1904.
    (f) Simpson. See 6 (h).
19. Simpson, *Phil. Mag.* **6**, 6, p. 589. 1903.
20. C. T. R. Wilson, *Phil. Trans*, **193**, p. 289. 1899.

21. Zölss. See 6 (*d*).
Simpson. See 6 (*h*).
22. Exner, *Terr. Mag. and Atm. Elec.* **5**, p. 167. 1900. Or *Met. Zeit.* p. 529. 1900.
23. (*a*) Elster and Geitel, *Phys. Zeit.* **1**, p. 247. 1900.
(*b*) ,, ,, *Über die Anwendung der Lehr von den Gasionen*, etc. Braunschweig. Vieweg u. Sohn. 1901.
24. Simpson, *Phil. Mag.* **6**, 6, p. 589. 1903.
25. Elster and Geitel, *Terr. Mag. and Atm. Elec.* **9**, p. 59. 1904.
26. (*a*) Ebert, *Phys. Zeit.* **5**, p. 135. 1904.
(*b*) ,, *Met. Zeit.* p. 201. 1904.
27. (*a*) Lüdeling, *Phys. Zeit.* **5**, p. 447. 1904.
(*b*) Jaufmann, *Met. Zeit.* p. 102. 1905.
28. (*a*) Gockel, *Met. Zeit.* p. 97. 1905.
Conrad. See 6 (*f*).
Mazelle. See 6 (*g*).
29. Simpson, *Phys. Zeit.* **5**, p. 325. 1904.
Ebert, ,, ,, **5**, p. 500. 1904.
Simpson, ,, ,, **5**, p. 734. 1904.
30. C. T. R. Wilson, *Nature*, **62**, p. 149. 1900.
31. Simpson. See 6 (*h*).
32. C. T. R. Wilson. See 30.
33. Gerdien. *Jahrbuch für Radioaktivität und Elektronik*, **1**, p. 34. 1904.

DISCUSSION.

The PRESIDENT (Mr. R. BENTLEY) said that the paper they had just heard illustrated in a striking manner the many changes that had taken place in the modes of meteorological study in recent years. For three centuries observations of barometric changes, temperature, wind near the surface, and lately of sunshine, had been recorded, and 60 years ago the discovery of ozone in the atmosphere was made by Schonbein. More recently still, the use of balloons and kites had increased our knowledge of the upper currents of the atmosphere, while in Germany and in England steady advance was being made in the analysis of the electrical state of the atmosphere. Mr. Simpson had modestly refrained from mentioning his own work, both here and abroad, in that direction ; but it could be seen from the paper how careful had been his labours, and he thought the Society was to be congratulated on the addition of his name recently to the List of Fellows.

Dr. W. N. SHAW said that it was remarkable to note the changes that had taken place in our ideas of statical electricity during the past 20 years or less. The old gold leaf electroscope was known to most in school-boy days. It used to be one of the first teachings of practical physics that if an electrometer was leaking the insulation of the supports was bad. Now the presence of a little radium was shown to make it leak, and that fact proved the starting-point of many investigations in electrical science. He noticed that the earliest reference in the paper was to 1886, and he was afraid that those who had not followed electrical advances since that date would have to unlearn much on taking up the subject again. Mr. Simpson had hurried over the effects of radio-active emanation in the atmosphere, but the fact of its existence, even though our knowledge of it was imperfect, was an important matter. We did not yet know its effect on human economy. The breathing out of radio-active emanations from spongy soils when the barometer falls may produce considerable effect upon people living under its influence. The difference between the bracing air of the east coast and the relaxing air of other places would escape the average observer with ordinary meteorological instruments, but with the use of the electroscope other influences may be found at work to account for the difference. Mr. Simpson had also dealt briefly with the relationship between ionization and thunderstorms, and suggested a distinction somewhat more definite than our

present knowledge of the subject warranted. In the origin of ions themselves there is no difference. He congratulated Mr. Simpson on the lucid way in which he had dealt with the subject.

Mr. W. B. Tripp said he was pleased to see an advance made in the direction of the paper, and he hoped in time that its connection with rainfall would be brought forward. He congratulated the Society on having made such a good beginning in the matter.

Capt. A. Carpenter asked if an explanation of the dissipation of fog by a heavy electric discharge, such as that advocated by Sir Oliver Lodge, could be given. Seeing that the ionization in a fog would be very low, would not the area cleared be very small?

Mr. R. Strachan said that the paper treated of atmospherical electricity in a manner entirely different from the usual one. In years gone by the distribution of electricity in the atmosphere was supposed to be due to the action of vapour and dust; now all is attributed to ions. To those brought up in the old school it is difficult to realise the meaning of electrons and ions, and he at present failed to see that their introduction helped matters. It is remarkable how the Germans have been the promoters of these new views. If they are accepted, much of our knowledge has to be disproved or extensively rectified. For himself he had much to learn from the paper, as the subject-matter seemed so novel.

Mr. C. Beadle thought that Mr. Simpson's explanation of the effect on the electroscope of lighting a match was hardly a feasible one. He considered that the flame was hardly close enough for combustion to affect the gold leaves, and wondered whether it was possible that the ions themselves radiated sufficiently from the flame to affect the leaves of the instrument.

Mr. G. C. Simpson, in reply, said that the causes which produce thunderstorms are different from those which produce the normal potential gradient; for although ions play a part in both phenomena the method of separation of the ions is different in the two cases. An explanation of Sir Oliver Lodge's experiments on fog was not easy; but the process might be the following. Consider a mass of gas containing a quantity of small particles of matter into which is introduced a wire charged to a high negative electrical potential. The ions already present would be set in rapid motion and cause fresh ionization. A large number of the positive ions would be attracted to the wire and removed from the mass, the remaining negative ions would attach themselves to the material particles, which, by electrostatical forces, would attract other particles and cause coagulation and so a reduction in the number of fog particles present. It was difficult to realise the present conception of electricity owing to the rapid change of ideas on the subject and the different schools at work. There are units of electricity as of oxygen, etc., and to these units, or elemental quantities of electricity, the name "electron" has been given. The combination of one or more electrons attached to a material particle is called an "ion." There is a great difference in the movements of electricity in a conductor and in the air. In a conductor electricity flows after the manner of water in a pipe; but in the atmosphere the electricity is attached to the molecules of air, and so cannot move without taking matter with it. The electricity in the charged clouds of thunderstorms is really an immense collection of ions of one kind, either positive or negative. Although the greater part of observational work on atmospheric electricity has been made in Germany, yet, as regards theory and the essentials which make the progress of the science possible, Englishmen are well to the front. Lord Kelvin, Mr. C. T. R. Wilson, and Prof. J. J. Thomson of Cambridge have done very important work in the science.

Aurora Borealis.

Commander M. W. C. Hepworth, R.N.R., Marine Superintendent of the Meteorological Office, has sent the following account of the Aurora Borealis observed by Capt. James J. Bailey, R.N.R., on board the S.S. *Brooklyn City* during a voyage between Bristol and New York:—

"September 18, 1905, at *8.30. p.m.*, 47°·35′ N., 43°·58′ W.—Observed Aurora Borealis showing at times over an arc of 160° on the horizon, a double arch, the lower of which reached at its apex the star Mizar in Great Bear, and was very brilliant and changing rapidly in intensity. The upper arch, which was separated by about 10° of arc and extended from Arcturus in the west through the Pole Star to Capella in the east, was much more faintly defined. Between the two arches, and emanating from apparently a common centre under the North Star, from the lower arch an incessant number of streamers of varying intensity were thrown to the upper arch, many frequently passing that and reaching right to the zenith. Towards midnight it was noticable that between the two arches the streamers appeared for the whole length to be ascending more perpendicularly, and apparently commencing at the lower arch, with at times an intensity equalling moonlight, and travelling very rapidly from west to east and back again.

"*Midnight.*—Both arches became completely broken up, merely representing so many individual patches of luminous light, with occasional bright streamers emanating from them.

"*1 a.m.*—The display terminated, leaving just a faint luminous glow high up along the northern horizon.

"*4 a.m.*—There was a recurrence of the Aurora Borealis, the one arch lying low along the horizon and throwing up short spiky streamers of no great altitude, but travelling backwards and forwards with great rapidity west to east, ending shortly before sunrise."

Meteorological Conference at Adelaide, May 1905.

In view of the possible transfer of the Observatory Departments to the Federal Government of Australia, as provided for in the Commonwealth Constitution Act, it was considered desirable that a Conference should be held of the official Directors of the Government Departments of the several States, to report on existing conditions, and to make recommendations for the future conduct of the services. This Conference met at Adelaide from May 10 to 16 under the presidency of Sir Charles Todd (South Australia), and was attended by Mr. H. A. Lenehan (New South Wales), Mr. W. S. Cooke (Western Australia), Mr. P. Baracchi (Victoria), Mr. A. A. Spowers (Queensland), and Mr. H. C. Kingsmill (Tasmania).

The Conference was of opinion that the establishment of one central meteorological bureau to supplant existing institutions, and to singly carry out the Australian weather services, is impracticable. The Conference thought that a central institution might be established for theoretical and scientific meteorology, but that the weather forecasts should be assured by each meteorologist for his own State, and for that State only.

TWO NEW METEOROLOGICAL INSTRUMENTS: 1. THE AUTOMATIC POLAR STAR LIGHT RECORDER; 2. THE OMBROSCOPE.

By S. P. FERGUSSON.

[Read June 21, 1905.]

The instruments described in this paper are not altogether new in principle, yet are not very well known. In the construction of these modified forms departures from the original patterns have been made chiefly for the purpose of securing automatic action so far as possible.

In its simplest form the Pole-Star Recorder has been in continuous satisfactory use at the Blue Hill Observatory since 1888. The automatic instrument described hereinafter was installed in April 1904. The Ombroscope has been in use since November 1903. Both instruments have proved so useful and valuable that I believe a brief description will be of interest to the Fellows of the Royal Meteorological Society.

1. Automatic Polar Star Light Recorder for Recording the Amount of Cloudiness at Night.

This instrument is a modification of the so-called "Pole-Star Recorder," probably first used by Prof. E. C. Pickering of Harvard College Observatory in 1885.

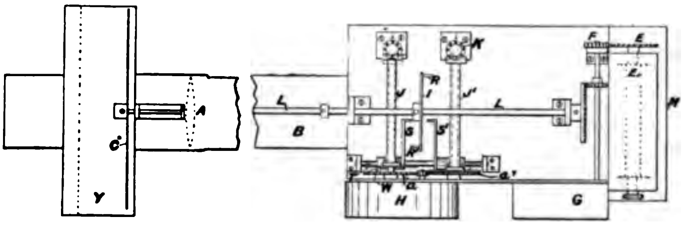


Fig. 1.

The principle of the instrument is that of a camera of long focus so mounted that the Polar star is permanently in the field. The Polar star is not at the true pole, but is about 1° 22′ distant from it; hence, if the camera is kept open all night the position of the star is photographed continuously, the "trail" of the star appearing as a circular arc, the radius of which will depend upon the length of focus of the instrument. If the night is clear the trail will be continuous; if partly cloudy the trail will be broken more or less, the breaks corresponding to obscurations of the star by clouds. The records are read by means of a transparent scale ruled with radial lines representing hours of time.

In the original instrument glass plates were used for records, the shutter was opened by hand and closed before dawn by an alarm clock. A dark room was necessary for proper manipulation of the plates, which were bulky and required special care for preservation. The present instrument is more nearly automatic, the shutter being opened and

closed at predetermined times, and a fresh portion of film (used instead of glass plates) moved into the field each day by the same mechanism—these processes being controlled by one clock, which is wound once a week. The film is changed once a week or twice a month, as desired, in daylight, at any time convenient. The working parts of the instrument are shown in Figs. 1 (plan), 2 (side elevation), and 3 (end section).

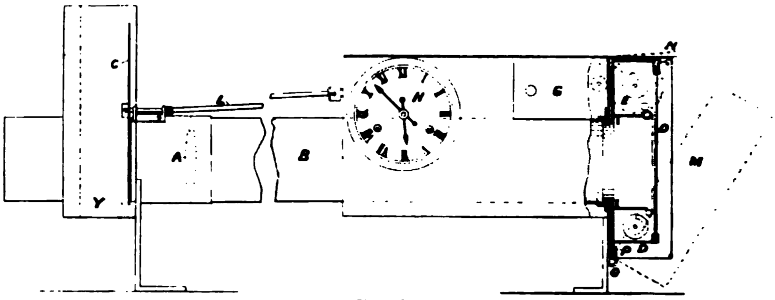


FIG. 2.

The lens, *A*, is mounted in a tube, *B*, one end of which is covered by a rotary disc shutter, *C*, contained within the case, *Y*. At the other end are mounted the devices for operating the shutter and film holder.

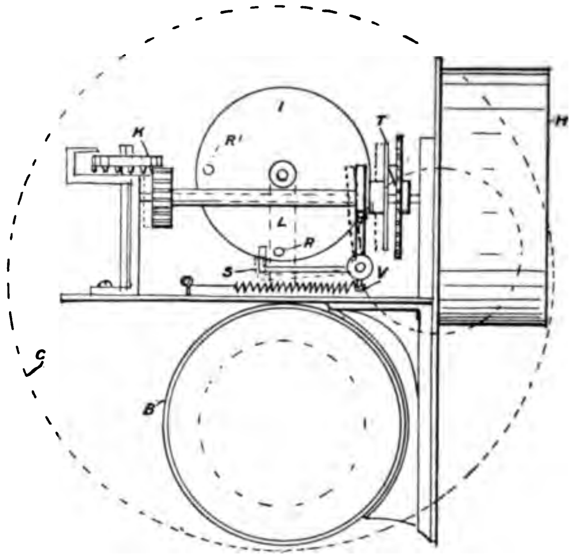


FIG. 3.

Within the case, *G*, is a strong clock mechanism operating the shutter, *C*, by means of the shaft, *L*, and gearing, in the following manner: The gears *a,a′* operated by the clock, *H*, revolve once in 24 hours; secured to the side of each gear is an inclined plane or cam, *W*, against which the disc, *T*, is held by means of the bent lever, *S*, (Fig. 3) and spring, *V*. Once during each rotation of the gear, *a*, the cam, *W*,

falls into a slot in the disc, T, allowing this disc to move toward the gear, a, as shown by the dotted lines. On the shutter-shaft, L, is secured a disc, I, to which are secured two pins, R,R', which are alternately stopped or blocked by the ends of the levers, S,S', except at the times when one or the other is released by the movements of the discs, T,T'. The discs are secured to hollow spindles, J,J', having on their outer ends pinions meshing with crown gears, K,K'. On the upper surface of each of these crown gears is a dial for indicating the time at which the pins, R,R', are released. The shutter-disc, C, is so mounted that when the pin, R', is stopped by the lever, S, the opening in the disc is opposite the open end of the tube, B, and a photograph is taken. When this pin, R', is released the shaft and shutter revolve until the pin, R, is stopped by the lever, S', and the end of the tube, B, is covered. The two positions of the aperture in the shutter-disc are shown by dotted lines in Fig. 3.

The gears, a,a', are so connected with the clock, H, that the time of

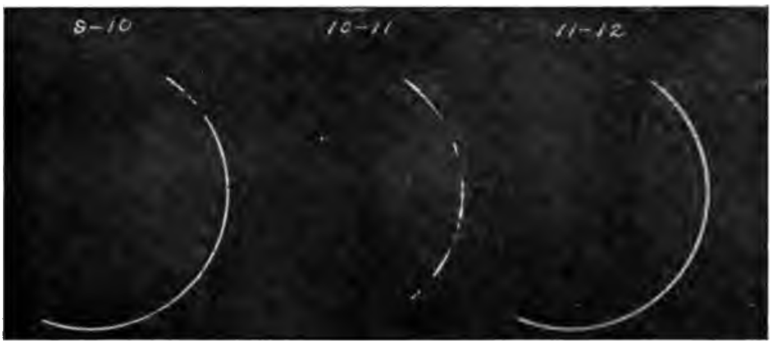


FIG. 4.—Copy of Star-Light Record, November 9-12, 1904. The records should be read from left to right. The small circles are trails of faint stars.

opening and closing the shutter is controlled by the regulation of the hands of this clock, the time error of the clock and of the shutter mechanisms being always the same.

The film holder, D,D, is similar in principle to the kodak camera, the usual key for turning the film being replaced by the gear E, in mesh with the pinion F, operated by the shutter mechanism G. At the time the shutter is opening or closing the film is being wound from the spool at the bottom of holder D, on to the spool E', one-half of the film necessary for one night's record being moved each time the shutter opens or closes. The film holder is retained in place by the spring latch N, and is supported in the groove P, so that it will always remain in the same position. This ensures uniform motion for the film, and accuracy in measuring the records. Dark slides are placed in both front and back of the film holder, so that films may be changed in daylight as are those of the well-known kodak cameras. When charged with film, and the clocks wound, the apparatus will work without attention until all the film is used. (Fig. 4.)

The instrument is usually mounted in a strong, tight, wooden box, as shown in Fig. 5. A short tube, Z, with vertical opening, keeps out most of the rain likely to fall into the instrument, but in winter it is some-

times necessary to cover this opening with a cap of clear glass, to prevent clogging with snow.

An automatic instrument similar to the one just described would probably cost about £50; but if the automatic devices for moving the film are dispensed with, a simple instrument of about 3 feet focus need not cost more than £4 or £5. A single lens of very ordinary quality, not costing more than four shillings, is good enough for the purpose; the other parts may be obtained of dealers in hardware and photographic supplies, and easily assembled by anyone of ordinary skill. With such

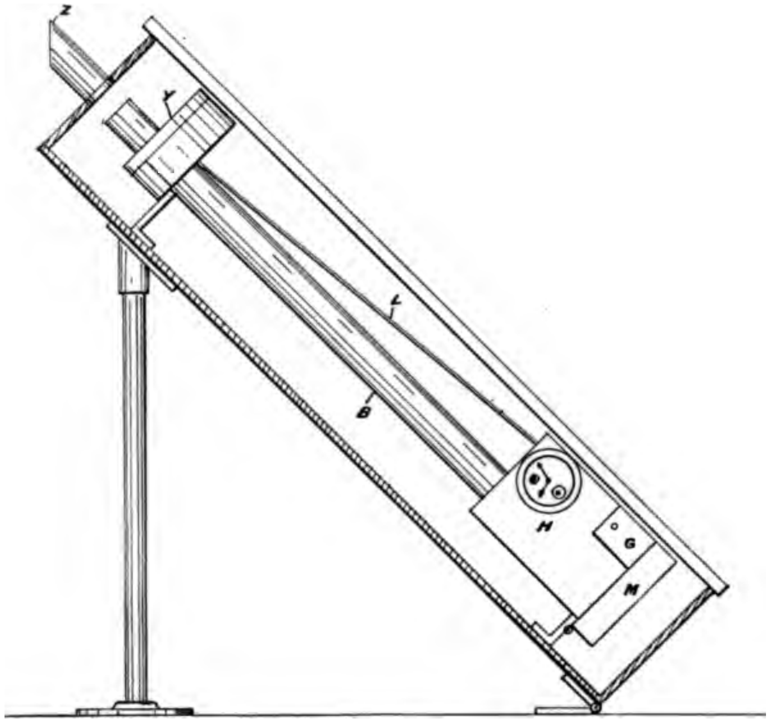


FIG. 5.

an instrument to supplement the sunshine recorder an observatory will be able to maintain at small cost a practically continuous record of the state of cloudiness.

In moderate north latitudes the Polar star is nearly half-way between the horizon and the zenith, hence records of cloudiness made at this point are quite near the true mean for the whole sky, and are more accurate than the records from the sunshine instruments because of the variable altitude of the sun. While the cloudiness determined from the automatic records of starlight sometimes differs from simultaneous estimates of the degree of cloudiness over the entire sky, the means of a number of observations and records agree quite closely, as shown in the following comparison. The figures are average percentages of the sky

covered by clouds, and of the time the Pole star was hidden, during the evenings of the year 1889.

1889.	7 P.M.		8 P.M.		9 P.M.		10 P.M.		11 P.M.	
	From Estimate.	From Recorder.	From Estimate.	From Recorder.	From Estimate.	From Recorder.	From Estimate.	From Recorder.	From Estimate.	From Recorder.
	%	%	%	%	%	%	%	%	%	%
January . . .	40	38	43	45	42	43	44	45	48	45
February . . .	40	38	39	40	45	42	46	44	46	48
March . . .	60	...	59	64	56	61	55	56	55	56
April	62	...	52	53	55	50	54	49	51	46
May	59	...	58	...	53	46	54	47	51	45
June	74	...	69	...	68	68	63	64	64	62
July	62	...	57	...	57	57	55	56	57	57
August . . .	41	...	40	...	38	37	43	45	47	49
September . . .	67	...	65	69	65	66	69	74	66	73
October . . .	57	...	59	64	61	64	64	63	65	64
November . . .	56	63	60	66	60	64	55	61	51	52
December . . .	50	45	48	49	53	54	49	52	50	55
Year	56	...	54	...	54	54	54	55	54	54

2. The Ombroscope, an Instrument for Determining the Time and Duration of Rain.

This instrument was devised for the purpose of recording the time of occurrence of very light precipitation that cannot be measured in the ordinary rain-gauges. Light showers or sprinkles of rain often are unnoticed by observers who, of course, cannot always remain on watch; also many general rains begin and end as a drizzle or mist, of which, especially at night, the time of occurrence is difficult to determine. Many light showers occurring at night evaporate before the rain-gauge is visited, and are not recorded by the automatic gauges.

For many researches accurate data concerning the time of rain are useful, and as early as 1860, M. Hervé-Mangon, of Paris, constructed an apparatus, very nearly identical with that described in this paper, for the purpose of studying the size and number of raindrops. This instrument was described in the *Annuaire de la Société Météorologique de France*, 1860, p. 183.

For a number of years the observers of the United States Signal Service exposed to the sky a piece of paper ruled with copying ink in order to ascertain if rain fell during the night, but no attempt to secure automatic registration appears to have been made.

In 1894 or 1895, Dr. O. L. Fassig, of the United States Weather Bureau, employed for this purpose a chronograph such as is used as a recording apparatus for anemometers, etc. This instrument proved satisfactory and very useful from the beginning, and from time to time improvements have been made as suggested by experience. The value of such an instrument had long been recognised at Blue Hill, and in 1903, encouraged by the success of Dr. Fassig's instrument, Mr. Rotch authorised the construction of a duplicate for addition to the equipment of the Observatory. While preparing the design for the new instrument an

improvement at once suggested itself to me. The record-cylinder of the so-called "anemometer-register" rotates four times in twenty-four hours, and while turning it is moved longitudinally by means of a screw on its axis, so that the record is in the form of a spiral, the sheet having four divisions corresponding to the four six-hour intervals. At the end of twenty-four hours, when the limit of the axial screw is reached, it is necessary to reset the cylinder whether rain has occurred or not; and as several rainless days sometimes occur in succession, it seemed desirable to make the new instrument automatic. With the exception of the changes of the mechanism necessary to obtain automatic action, the principle of the apparatus is nearly the same as that of Dr. Fassig's instrument.

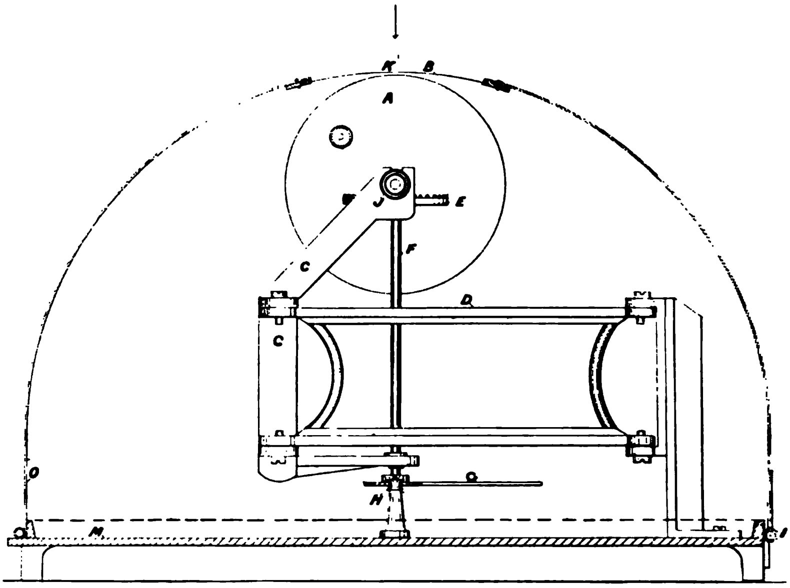


Fig. 6.

The Ombroscope (shown in Figs. 6 and 7) consists essentially of a clock-cylinder, *A*, supported by a swinging frame, *C*, *C*, *D*, *D*, covered by a sheet-metal casing, *O*. At the top of the casing is a sheet of mica, *B*, in which is a small aperture, *K*. Around the cylinder, *A*, is wrapped a sheet of paper covered with fine lines ruled with transfer or copying-ink. Raindrops falling through the aperture *K* on the cylinder, blur the lines more or less as shown by the specimen record, and as the cylinder rotates the occurrence of even a small drop of rain is shown at once. The cylinder is caused to rotate by clamping the clock-spindle, *P*, by means of the milled head, *J*. As the cylinder revolves, the cam, *G* (by means of the gearing and spindle *E*, *F*, *N*), is caused to turn once in twenty-four hours, and move the cylinder and its supporting framework from one side of the casing to the other, as shown by the dotted lines. At the end of each period of twenty-four hours the frame and cylinder swing back to the starting-point, the cam being held against the roller, *H*, by gravity.

There being four rotations of the cylinder in twenty-four hours the record sheets are ruled with four divisions, so that the cylinder may be placed in the proper position with reference to the aperture, *K*. The casing, *O*, is hinged at *I*, for convenience in inspecting the apparatus.

The accuracy of apparatus of this kind depends upon the ratio of the width of the aperture, *K*, to the speed of the paper, and upon the distance of the aperture from the surface of the cylinder. If, as in the instance of the Blue Hill instrument, the aperture is equal in width to one five-minute division of the record sheet the maximum error may be five minutes. Increasing the speed of the paper would reduce the probable error, but this would increase the bulk and the cost of the instrument if the automatic feature is retained. The distance of the aperture from the surface of the cylinder is just sufficient to prevent

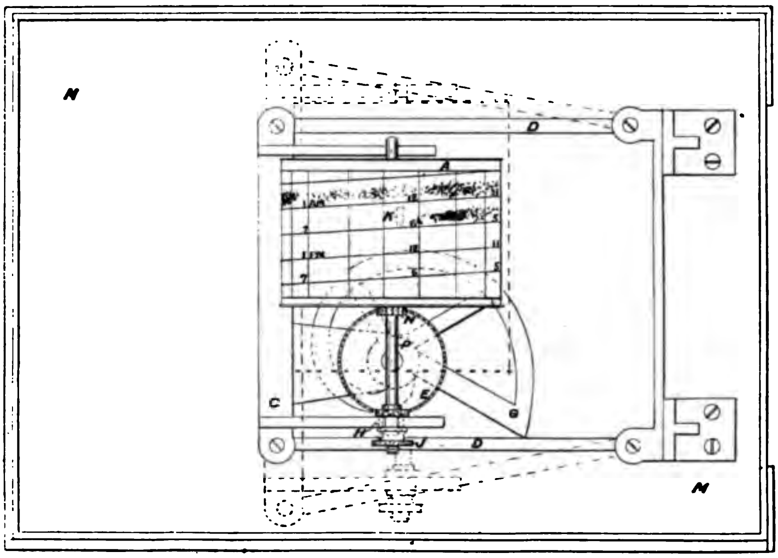


FIG. 7.

drops adhering to the edge of the aperture from touching the paper. It was found by actual trial that if this distance was less than 0·12 in. a drop forming on the edge of the aperture would sometimes be dragged half-way around the cylinder, thus blurring the paper and spoiling the record. If the distance is much greater rain that falls during a strong gale will be driven under the edges of the aperture sometimes to a distance equal to the width of the aperture. Errors of this kind, however, may be corrected by allowing for the direction and velocity of the wind.

The sensitiveness of the instrument depends upon the size of the aperture *K*, but it has been found that an aperture 0·4 inch square is sufficiently large. A sheet of paper ruled into squares, each equal in size to the aperture, *K*, was exposed to a very light rain, the amount of which was too small to be measured. There were about 300 squares, and in five minutes all but ten contained one or more drops. In ten

minutes all the squares contained more than one drop each. Hence, from this experiment and from other data of observation it is safe to assume that this instrument will record the time of occurrence of rain with much greater accuracy than is possible by any other method.

The time when rain changes to snow or snow changes to rain has been determined with considerable accuracy from some of the records, such data usually being quite difficult to obtain during the night.

Since the Ombroscope was installed there has been a decided increase in the number of occurrences of rain recorded, also the comparisons so far made of the automatic records with the observations, have fully demonstrated the superior accuracy of the former.

Royal College of Physicians of Edinburgh, Parkin Prize.

In terms of the bequest made to the Royal College of Physicians of Edinburgh by the late Dr. John Parkin, Fellow of the College, a prize is offered for the best essay on certain subjects connected with medicine.

The subject of the essay for the present period is, in terms of the deed :—

"On the effects of volcanic action in the production of epidemic diseases in the animal and in the vegetable creation, and in the production of hurricanes and abnormal atmospherical vicissitudes."

The prize is of the value of one hundred pounds sterling, and is open to competitors of all nations.

Essays intended for competition, which must be written in the English language, to be received by the Secretary not later than December 31, 1906. Each essay must bear a motto, and be accompanied by a sealed envelope bearing the same motto outside, and the author's name inside.

The successful candidate must publish his essay at his own expense, and present a printed copy of it to the College within the space of three months after the adjudication of the prize.—HARRY RAINY, M.D., *Hon. Sec.*

Atmospheric Difficulties in South-West Africa.

"Among the difficulties the German forces operating against the Hereros in South-West Africa have to contend with," says *The Times*, September 11, 1905 (quoting from the *Militar-Wochenblatt*), "are certain atmospheric ones. The land being high above the sea-level, the balloons had less lifting power than in Germany, and the stretch of cable often fell below the demanded 220 yards. The dryness of the atmosphere set up frictional electricity, which at times threatened to set the balloons on fire. The atmospheric electrical disturbance was greater than in Germany, especially in the rainy season and in the evening. There was generally freedom from this disturbance between 5 and 9 a.m. Strong whirlwinds were frequent, particularly at midday, and the balloons or kites were sometimes hurled perpendicularly into the bush and much torn. On one occasion the bush was occupied by the enemy, and the balloon had to be rescued from them. Some balloons were carried right away by the wind and were lost, or burst by the air pressure. The balloon, while serving to reveal the whereabouts of one column to other columns, also revealed the presence of the column to the enemy. The combined heat and dryness caused the boxes containing the apparatus to crack, and they then admitted the dust. The heat and dryness also had a ruinous effect upon the wheels of the vehicles, and the rough travelling had injurious effects on the whole outfit. The supplies of gas, benzine, and balloon and kite material ran short. Altogether, campaigning with wireless telegraphy in South-West Africa was quite a different thing from experiences with wireless telegraphy on a field day at home."

CLIMATOLOGICAL OBSERVATIONS AT AN ARCTIC STATION IN REPULSE BAY.

By Commander M. W. CAMPBELL HEPWORTH, R.N.R., C.B., F.R.A.S.
Marine Superintendent of the Meteorological Office.

Repulse Bay is situated at the head of Rae's Welcome, an inlet to the north of Hudson's Bay, and of Frozen Strait, which separates Melville Peninsula from Southampton Island. It is separated from the Gulf of Boothia by Rae Isthmus, the Gulf bearing about north by west true from its western extremity; the Bay lies comparatively open to south-eastward. Captain, afterwards Rear-Admiral, Sir Edward Parry, visited and explored the Bay and its neighbourhood in 1821, during his second voyage for the discovery of a north-west passage to the Pacific.

He found that the rising land on the northern and western sides of the Bay did not exceed six or seven hundred feet in height, while that to the south rose, perhaps, full a thousand feet above the level of the sea.

In the service of an Exploration and Whaling Company, Captain John A. Murray, a whaling master of considerable experience, passed the winter and spring of 1903-4 in Repulse Bay. He had wintered in the same locality in 1895-6, when he experienced some extremely low temperatures. Before sailing for Hudson's Bay in the spring of 1903, with his brother Captain Alex. Murray of the whaler *Active*, Captain John Murray expressed a wish to make and record observations for the Meteorological Council, and was by them provided with the instrumental equipment necessary for carrying on this work.

The instruments were as follow :—Barometer, 3 Spirit Thermometers, Maximum Thermometer, 2 Minimum Thermometers; Raingauge (8 inch), and Stevenson Screen.

In regard to the salient features of the country in the immediate neighbourhood of Repulse Bay, Captain Murray states that the land is comparatively high on the eastern as well as on the southern side of the Bay, and that it rises to an elevation of about 1500 feet on the former side.

The observations contributed by this observer were made on board, or in the immediate vicinity of a small vessel belonging to the Whaling Company's station there. This vessel was anchored, and subsequently frozen in, among some islands in latitude 66° 30′ N., longitude 86° 20′ W., which position is about two and a half to three miles off the northern shore of the Bay, and to the south-west of a small bight called Haviland Bay.

The Meteorological Register was commenced on October 24, 1903, and was kept daily until June 7, 1904. The few days' observations for the opening and closing months have not been dealt with for obvious reasons. During this period observations of Wind, Pressure, Temperature, Humidity, Cloud, and Weather were made and recorded four times daily; and these observations were occasionally supplemented by various useful remarks. The hours of observation were 8 a.m., noon, 4 p.m., and 8 p.m.

The records of Pressure are from a mercury barometer kept in a

REPULSE BAY (66° 30′ N., 86° 20′ W.).

1903-1904.

Month.	Air Temperature.—Extremes.					
	Date.	Hour.	Absolute Maximum.	Wind. Direction.	Wind. Force.	Weather.
November .	6	8 p.m.	° 28	NW	3	bc
December .	12	Noon	14	E	5	o
January . .	12	8 a.m.	6	SE	1	c
February . .	4	8 p.m.	10	ESE	6	b
March . .	7	8 a.m.	− 6	Calm	0	s
April . .	28	Noon	30	NNE	1	c
May . .	21	Noon 4 p.m.	33	Calm SW	0 1	o
May . .	31	4 p.m.	33	E	1	s
Period . .	...	...	33	...	...	...

Month.	Air Temperature.—Extremes.					
	Date.	Hour.	Absolute Minimum.	Wind. Direction.	Wind. Force.	Weather.
November .	24	8 a.m. 4 p.m.	° − 18	NW N	1 1	b
December .	31	8 p.m.	− 29	NNE	6	b
January . .	19	4 p.m. 8 p.m.	− 46	NNE	4	b
February . .	28	8 a.m.	− 51	NNE	2	b
March . .	2	8 p.m.	− 56	NNE	10	s
April . .	1	8 a.m.	− 33	N	3	b
May . .	4	8 a.m.	− 2	NNE	3	b
Period . .	...	...	− 56	...	...	...

Month.	Barometer.						Air Temperature.—Means.			
	Mean.	Absolute. Max.	Absolute. Min.	Range.	No. of Observations. Max. over 30 ins.	No. of Observations. Min. under 29 ins.	Mean.	Mean Max.	Mean Min.	Daily Range.
	ins.	ins.	ins.	in.			°	°	°	°
November	29·78	30·62	28·94	1·68	11	1	2·7	5·9	− 0·6	6·5
December	29·62	30·17	29·17	1·00	1	0	− 11·1	− 7·9	− 14·3	6·4
January .	29·82	30·31	29·40	0·91	12	0	− 26·3	− 24·0	− 28·6	4·6
February .	29·87	30·58	28·93	1·65	15	1	− 31·0	− 26·8	− 35·3	8·5
March .	29·97	30·80	29·25	1·55	17	0	− 27·5	− 21·0	− 34·1	13·1
April .	30·02	30·14	29·15	0·99	21	0	− 1·5	4·5	− 7·6	12·1
May .	29·81	30·45	28·82	1·63	11	2	17·6	21·7	14·2	7·5
Period .	29·84	30·80	28·82	1·98	88	4	− 11·0	− 6·8	− 15·2	8·4

small wooden house built for the purpose on the deck of the vessel; the sides of the house were backed with bricks of snow. The thermometer screen, prior to December 27, 1903, and after May 17, 1904, was situated on the upper deck near the foremast, raised 4 feet above the deck; but between the dates mentioned it was erected on a snow bank which had formed round the vessel's side, and presumably the base of the screen was about 4 feet above the surface of the snow.

The results of Captain Murray's observations, reduced and tabulated, are given herewith, and as they form a valuable supplement to these tables, the results of observations made at Fort Hope, on the north shore of Repulse Bay, by John Rae, M.D., F.R.G.S., during two sojourns there, in the years 1846-7 and 1853-4, are added. Dr. Rae's station, in 66°·32′ N., 86°·56′ W., was about fifteen miles to the westward of the position assigned by Captain Murray to that of his own winter quarters.

The results of Dr. Rae's observations are embodied in Part I. of a work entitled *Contributions to our knowledge of the Meteorology of the Arctic Regions*, published by the authority of the Meteorological Council in 1879. It is compiled by Mr. Richard Strachan, F.R.Met.Soc., late of the Meteorological Office, and forms the first instalment of an important investigation.

Temperature.—It will be seen from the tables that during the seven months, November to May, of Captain Murray's stay at Repulse Bay,

REPULSE BAY (66° 30′ N., 86° 20′ W.).

1903-1904.

Month.	Percentage of Wind Frequency.								
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
November	31	34	5	4	5	7	5	5	4
December	41	38	15	2	...	...	...	2	2
January	43	32	4	6	5	2	1	6	1
February	44	28	4	3	5	3	3	3	7
March	42	27	5	4	2	1	2	2	15
April	39	22	2	5	13	5	1	3	10
May	34	10	15	12	10	4	5	4	6
Period	39	27	7	5	6	3	2	4	7

Month.	Mean Wind Force.								Gales.	
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	No. of Days.	Max. Force.
November	3	3	5	4	4	3	2	3	6	9
December	4	5	5	6	...	...	...	1	12	10
January	2	3	4	3	3	1	4	3	1	7
February	3	4	2	2	2	2	3	3	5	10
March	4	5	2	3	1	3	3	1	5	10
April	3	4	2	4	3	2	1	2	3	10
May	2	4	3	4	4	2	2	3	4	10
Period	3	4	3	4	3	2	2	3	36	10

the mean temperature in the screen varied from $-31°$ in February to $+17°·6$ in May; and that the mean daily range for the seven months was $8°·4$. The highest absolute maximum recorded during the period was 33° in May, and the lowest absolute maximum $-6°$ in March; while the lowest absolute minimum was as low as $-56°$ in March, and the highest absolute minimum $-2°$ in May.

The highest temperatures occurred during light airs and calms, or when there was a gentle breeze from North-west; with minima temperatures the winds came from Northward; the lowest temperatures being associated with winds from North-north-east, of varying force, and the $-56°$ reading with a whole gale from that point. With maxima temperatures the "Weather" varied, but with minima temperatures "Blue sky" was almost always associated.

REPULSE BAY (66° 30′ N., 86° 20′ W.).

1903-1904.

Month.	Weather. Percentage of Frequency.						No. of Instances.			
	b.	bc.	cb.	c.	o.	s.	d.	p.	m.	Aurora.
November	34	14	6	10	36	5	0	0	0	1
December	29	12	7	8	44	23	0	0	1	1
January	64	3	2	3	28	14	0	0	1	1
February	58	12	11	4	15	6	0	0	0	1
March	60	13	6	2	19	15	0	0	0	3
April	41	10	5	9	35	19	0	0	0	1
May	14	10	10	9	57	28	3	1	0	0
Period	43	11	7	6	33	16	3	1	2	8

Pressure.—The tables show the absolute range of the barometer for the seven months to have been 1·98 in., the highest reading, 30·80 ins., being recorded in March, and the lowest, 28·82 ins., in May. From an examination of the barometer readings of the whole period, it is found that of 213 days' maxima there were 88 days on which a maximum above 30 ins. was recorded, but only 4 days on which the minimum was below 29 ins. The greatest range of the barometer for any month was 1·65 in., and occurred in February; the smallest range for any month 0·91 in. in January.

Wind.—The prevailing winds were from Northward; not less than 66 per cent of the wind observations were either of North or North-east winds; 27 per cent were almost equally distributed between the remaining cardinal and intercardinal points, and 7 per cent were calms. Dr. Rae's records allot a North or North-west direction to 59 per cent of his wind observations; 30 per cent to the remaining cardinal or intercardinal points, fairly equally divided; and 11 per cent to calms.

During Captain Murray's stay calms were most frequent in March, April coming second in order of frequency, the percentage being 15 in the former month and 10 in the latter. During Dr. Rae's two years they were most frequent in February, July, and September; least frequent in January and March.

Although Captain Murray's station lay comparatively open between south by east and south-east by east, winds from Southward and South-eastward were rare. In April a Southerly air current occasionally visited the station, and in May the Southerly tendency was rather more marked.

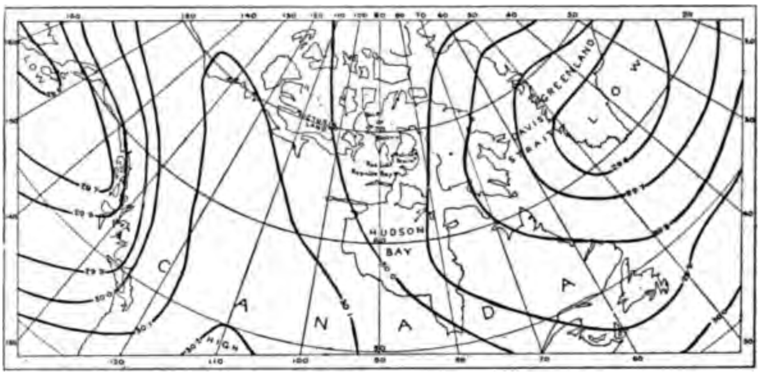


Fig. 1.—Mean Isobaric Lines for December.

Pressure is relatively low to the Eastward and North-eastward of Hudson's Bay and Melville Peninsula, and relatively high to the Westward and North-westward of those regions at all times of the year, but during the winter months this distribution of pressure is considerably more marked (Figs. 1 and 2, reproduced from the *Report of the Scientific Results of the Voyage of H.M.S. Challenger*). It is, therefore, to be expected that the predominating winds, especially in winter, would be from Northward.

Fig. 2.—Mean Isobaric Lines for March.

Gales were most prevalent in December, but the strongest recorded did not exceed force 10 of Beaufort scale. In this month it will be noticed that the wind was almost always in a Northerly, North-easterly, or Easterly quarter, calms were rare, and the mean wind force was 6. January was a quiet month, the wind attaining gale force on one day only, and then not exceeding 7 of Beaufort scale. Gales occurred on thirty-six days, and on all but seven of them the maximum force reached 10, or that of a whole gale.

Weather.—As regards the "state of the weather" during the perioc by referring to the tables it will be seen that the clearest months wer January, February, and March, when the wind was mainly from Northerly or North-easterly quarter. · In January 67 per cent of th

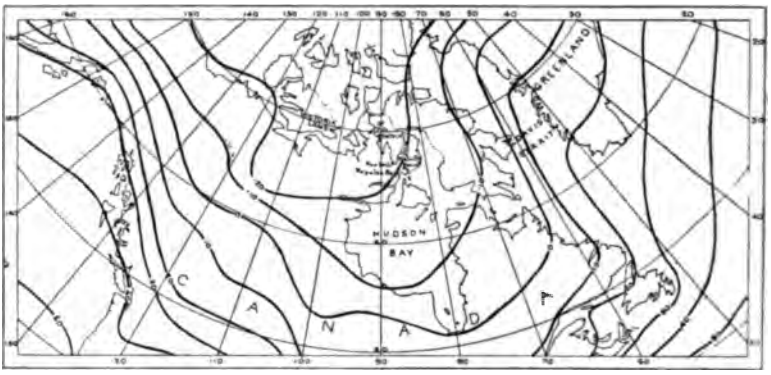


FIG. 3.—Mean Isothermal Lines for December.

observations under the head "Weather" are of "Blue Sky" or "Blu Sky and Detached Clouds"; in February 70 per cent are of the sam character, and in March 73 per cent. The cloudiest months wer November, with 46 per cent of observations "Detached Clouds" o "Overcast"; December with 52 per cent of the same character, and Ma with 66 per cent.

In December and May most snow fell, the largest fall occurring i

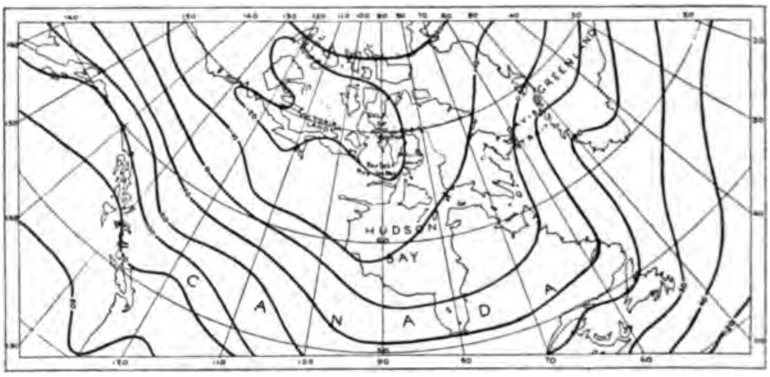


FIG. 4.—Mean Isothermal Lines for March.

the latter month, when the percentage of frequency was 28. Snow fell most frequently with winds from North-north-east, and, rather less frequently with winds from South. Occasional falls of snow occurred with winds from all points except west-south-west; the entry "S" is not once associ ated with a wind direction from that point of the compass. The amount of the snowfall for the twenty-four hours is not recorded, probably on account of the difficulty experienced in obtaining an accurate measurement.

Eight instances of Aurora were recorded; three of these occurred in March.

RESULTS OF DR. RAE'S OBSERVATIONS.

Temperature.—Dr. Rae records maximum temperatures with winds from all quarters during both of his sojourns in Repulse Bay. His observations in August, on each occasion, were too scanty for discussion. During his first period the lowest temperatures were associated with winds from North and North-west; but during his second period with winds from all quarters, and with calms. His absolute minimum for the winter 1853-4, – 50°, occurred when the wind was from West.

The range of temperature during the first period was 101°; the absolute maximum being 57° in July, and the absolute minimum – 44° in January; the range during the second period was 109°; the absolute maximum of 59° being recorded again in July, and the absolute minimum – 50° in February; but January had a – 48° reading, and December one of – 44°.

REPULSE BAY (66° 32′ N., 86° 36′ W.).

(This is about 15 miles west of the ship station.)

AIR TEMPERATURE—EXTREMES.

1846-47.

MONTH.	Date.	Hour.	Absolute Maximum.	Wind.		Weather.
				Direction.	Force.	
			°			
September .	15	Noon	45	SSE	4	cps
October . .	4	Noon	38	SE	4	hpr
November .	3	6 p.m.	27	ESE	4	oms
December .	10	8 a.m.	17	NE	4	os
January . .	23	7 p.m.	– 9	NNW	9	o
February . .	11	Noon	– 7	NNW	5	os
March . .	16	Noon	– 6	NNW	5	bcs
April . .	13	Noon	21	NNW	...	...
May . .	29	Noon	45	S	...	...
June . .	24	Noon	47	Calm	0	bc
July . . .	21	Noon	57	Calm	0	bc
August . .	...	...	...	...	...	...
Period . .	...	...	57	...	...	...

MONTH.	Date.	Hour.	Absolute Minimum.	Wind.		Weather.
				Direction.	Force.	
			°			
September .	23	6 a.m.	16	WNW	3	b
October . .	22	6 a.m.	– 13	NW	2	bcf
November .	29	6 p.m.	– 23	WNW	3	b
December .	26	6 a.m.	– 36	NNW	10	bcm
January . .	8	7 a.m.	– 44	NW	2	b
February . .	16	6 a.m.	– 39	NNW	7	bm
March . .	1	6 a.m.	– 42	NNW	1	b
April . .	19	6 a.m.	– 23	NNW	...	...
May . .	5	6 a.m.	– 3	NNW	...	...
June . .	1	6 a.m.	13	...	...	...
July . . .	1	9 p.m.	29	N	5	bc
August . .	...	...	...	...	...	...
Period . .	...	...	– 44	...	...	...

REPULSE BAY (66° 32′ N., 86° 36′ W.).
(This is about 15 miles west of the ship station.)

AIR TEMPERATURE—EXTREMES.

1853-54.

Month.	Date.	Hour.	Absolute Maximum.	Wind.		Weather.
				Direction.	Force.	
September .	2	8 a.m.	° 41	Calm	0	ps
October .	13	8 p.m.	35	SE	6	r
November .	3	2 p.m.	13	NW	3	s
December .	31	2 p.m.	22	N	5	os
January .	1	8 p.m.	18	SE	3	os
February .	18	8 a.m.	-18	NNW	6	bcm
March .	29	8 p.m.	10	W	5	o
April .	29	2 p.m.	43	NW	3	f
May .	29	2 p.m.	45	S	4	c
June .	10	2 p.m.	54	NNW	5	bc
July .	16	2 p.m.	59	SW	9	bc
August .	...	...	...	...	...	...
Period .	...	...	59	...	...	...

Month.	Date.	Hour.	Absolute Minimum.	Wind.		Weather.
				Direction.	Force.	
September .	24	8 p.m.	° -2	Calm	0	ps
October .	29	8 p.m.	-17	SE	2	bc
November .	23	8 p.m.	-40	NNE	2	b
December .	5	8 p.m.	-44	Calm	0	bc
January .	31	8 p.m.	-48	NNW	4	bm
February .	7	8 p.m.	-50	W	4	b
March .	8	8 a.m.	-38	Calm	0	bc
April .	1	8 a.m.	-32	SE	2	bc
May .	4	8 p.m.	2	N	10	b
June .	13	8 p.m.	29	Calm	0	bc
July .	1	8 p.m.	34	E	7	r
August .	...	...	...	...	...	...
Period .	...	...	-50	...	...	...

Pressure.—For the eleven months, September to August, of the period 1846-7 the absolute range of the barometer was 1·54 in.; the highest reading, 30·74 ins., being observed in March, and the lowest, 29·20 ins., in June. The range is not so large as that experienced by Captain Murray in the seven months, November to May, of 1903-4, but the maximum pressure was reached in the same month in both periods.

Light winds, clear weather, and low temperatures appear to have accompanied the highest pressures recorded by Dr. Rae during his first stay at Repulse Bay; unfortunately records of pressure are not available for 1853-4.

Wind.—The commonest winds during the two eleven-months periods were from Northward and North-westward, the percentage of frequency being 31 for North winds and 28 for North-west. In December 74 per cent of all wind observations were either of North or of North-west winds;

in January 81 per cent; in February 62 per cent; and in March 77 per cent. Winds from South-west were least frequent, and those from South and from North-east were rare.

The strongest winds blew from Northward and North-westward, the lightest from Southward and South-eastward.

REPULSE BAY.

1846-47, 1853-54.

Percentage of Wind Frequency.

Month.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
September	20	2	12	9	4	3	11	24	15
October	21	5	6	8	5	3	2	40	10
November	24	4	7	6	3	0	6	39	11
December	50	5	3	1	2	0	5	24	10
January	40	1	1	2	0	1	8	41	6
February	30	1	1	1	2	4	13	32	16
March	47	3	0	2	5	1	6	30	6
April	31	5	3	17	7	2	9	17	9
May	32	7	11	4	5	5	12	16	8
June	23	7	11	12	4	0	8	24	11
July	28	9	8	5	2	3	11	17	17
August	...	...	...	...	...	...	...	...	...
Period	31	4	6	6	4	2	8	28	11

Mean Wind Force.

Month.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
September	5	6	6	5	4	6	4	5
October	7	4	6	5	4	3	4	6
November	6	4	3	3	3	5	5	4
December	6	4	4	3	3	2	3	5
January	6	1	4	3	...	1	2	6
February	5	1	1	1	3	3	3	4
March	6	5	...	3	3	6	4	5
April	6	3	4	2	3	2	2	3
May	6	5	4	3	3	4	5	4
June	6	6	5	4	3	3	6	7
July	7	7	4	3	3	7	5	6
August	...	...	...	...	...	...	...	...
Period	6	4	4	3	3	4	4	5

Weather.—The finest weather during Dr. Rae's two periods, 1846-7 and 1853-4, appears to have been experienced in the months of February, March, and May; the worst weather in September, October, and June. Rain was most frequent in June and July; snow in September and October, but the percentage of snow-frequency was comparatively large also in November and December.

January and June were the most squally months. From November to March, both inclusive, there was most mist or haze; and in April and July most fog. On June 1854 there occurs an entry: "Rain all night with thunder," and this is the only instance of thunder recorded by Dr.

Rae; thunderstorms are rare in the Arctic Regions. On September 30, 1846, hail was recorded at 6 a.m., and in October of the same year entries of hail occur six times at 6 a.m., five times at noon, and twice at 6 p.m. Aurora was observed on thirty-nine occasions, of these thirteen were in the month of January. The absence of results for August is regretable, but it may here be mentioned that, in alluding to the conditions which obtained in the middle of August 1821, Parry wrote: "Nothing could exceed the fineness of the weather about this time; the climate was, indeed, altogether so different from that to which we had been accustomed in the icy seas as to be a matter of constant remark. The days were temperate and clear, and the nights not cold, though a very thin plate of ice was usually formed upon the surface of the sea in sheltered places and in pools of water among the floes."

REPULSE BAY (66° 32′ N., 86° 36′ W.).

1846-7, 1853-4.

Month.	Weather. Percentage of Frequency.								Aurora. 1846-7. No. of Instances.
	b.	c.	o.	m.	f.	r.	s.	q.	
September	18	28	54	2	0	4	32	3	1
October	17	23	60	6	3	1	42	5	6
November	28	34	38	38	1	0	22	2	8
December	31	38	31	37	0	0	23	3	8
January	35	40	25	51	0	0	11	8	13
February	42	48	10	45	0	0	8	3	2
March	40	50	10	55	0	0	8	3	0
April	30	43	27	0	4	0	4	4	1
May	45	41	14	0	1	0	5	0	0
June	21	23	56	0	0	26	11	7	0
July	28	31	41	0	4	20	3	5	0
August	...	...	...	...	...	...	...	...	...
Period	31	36	33	21	1	5	15	4	39

On June 9, 1854, "rain all night with thunder." This is the only instance of thunder. On Sept. 30, 1846, hail was recorded at 6 A.M.; and also in October six times at six A.M., five times at noon, and twice at six P.M.

Month.	Barometer, 1846-1847.				Air Temperature. 1846-7. 1853-4.
	Max.	Min.	Range.	Mean.	Mean.
	ins.	ins.	in.	ins.	°
September	...	...	...	...	27
October	30·19	29·35	0·84	...	12
November	30·66	29·39	1·27	29·93	− 8
December	30·55	29·49	1·06	30·06	− 21
January	30·26	29·22	1·04	29·79	− 29
February	30·56	29·71	0·85	30·15	− 30
March	30·74	29·45	1·29	30·17	− 20
April	...	...	...	...	1
May	...	...	...	...	21
June	30·18	29·20	0·98	...	34
July	30·25	29·63	0·62	29·92	42
August	...	...	...	...	...
Period	30·74	29·20	1·54	...	3

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 17, 1905.

Ordinary Meeting.

Capt. D. Wilson-Barker, F.R.S.E., Vice-President, in the Chair.

Capt. J. J. Alsop, c/o Messrs. Shaw, Saville and Co., 14 Billiter Street, E.C.;
William Pike Gibbons, J.P., Ruiton House, near Dudley;
Stephen William Savin Morris, Cape Town, Cape Colony;
Charles George Trevett, 15 Castle Street, Cape Town; and
Rev. Herbert William Williams, 421 Holloway Road, N.,
were balloted for and elected Fellows of the Society.

The following communications were read:—

1. "Measurement of Evaporation." By Richard Strachan, F.R.Met.Soc. (p. 277).

2. "Logarithmic Slide-Rule for reducing Readings of the Barometer to Sea Level." By John Ball, Ph.D., Assoc.M.Inst.C.E. (p. 285).

June 21, 1905.

Ordinary Meeting.

Richard Bentley, F.S.A., President, in the Chair.

Samuel Murphy Walford Bodie, M.D., The Manor House, Macduff, N.B.;
Lemuel Arthur Crosse, J.P., Nqutu, Natal, South Africa;
Rennie Malcolm Kerr, Gokak Falls, India;
Capt. Henry George Lyons, R.E., Cairo, Egypt; and
Frederick Sadler, 3 Hereford Road, Acton, W.,
were balloted for and elected Fellows of the Society.

The following communications were read:—

1. "Normal Electrical Phenomena of the Atmosphere." By G. C. Simpson, B.Sc., F.R.Met.Soc. (p. 295).

2. "Two New Meteorological Instruments: (1) Automatic Polar Star Light Recorder, and (2) The Ombroscope." By S. P. Fergusson (p. 309).

CORRESPONDENCE AND NOTES.

Report of the Lightning Research Committee.

A note on the constitution, and on the proposed work of the Lightning Research Committee, was given in the *Quarterly Journal*, vol. 27, p. 184. The Committee was organised by the Royal Institute of British Architects and the Surveyors' Institution, and also included a representative from the Royal Meteorological Society, viz. Dr. W. N. Shaw, F.R.S.

The Report of the Committee, which contains a preface by Sir Oliver Lodge, F.R.S., has been published in the *Journal of the Royal Institute of British Architects*, 12, No. 13, pp. 405-428.

The following extracts will show the main conclusions of the Committee:—

"As far as the Committee are able to judge from the newspaper reports which have reached them, the number of reported cases of buildings damaged by lightning in Great Britain during the three years 1901-1904 amounted to over five hundred. Altogether the Committee have had before them detailed reports from their observers of the damage done in 115 cases. Seventy-five cases related to buildings which were without any form of protection. The remaining forty were provided with what had been considered by those responsible for the buildings as sufficient safeguards in the way of lightning rods. While taking due account of the lessons to be learnt from the action of the lightning on unprotected buildings which have been injured, the Committee have deemed it unnecessary for the purposes of this Report to go into the details of these cases. A selection, however, has been made from the reports of "protected cases," and these are summarised and put into tabular form in an appendix, with observations in some instances of the conditions which appear to the Committee to have contributed to the failure of the means of protection provided.

"It has been pointed out by Sir Oliver Lodge that lightning discharges are of two distinct characters, which he has named the A flash and the B flash respectively. The A flash is of the simple type, which arises when an electrically charged cloud approaches the surface of the earth without an intermediate cloud intervening, and under these conditions the ordinary type of lightning conductor acts in two ways, first, by silent discharge, and secondly, by absorbing the energy of a disruptive discharge. In the second type, B, where another cloud intervenes between the cloud carrying the primary charge and the earth, the two clouds practically form a condenser; and when a discharge from the first takes place into the second, the free charge on the earth side of the lower cloud is suddenly relieved, and the disruptive discharge from the latter to the earth takes such an erratic course that no series of lightning conductors of the hitherto recognised type suffice to protect the building.

"It may be considered that a lightning conductor of the ordinary type, if properly constructed, affords an undefined area of protection against A flashes; but it cannot be said to have any protective area against B flashes.

"Absolute protection of the whole of a building could only be assured by enclosing the structure in a system of wirework—a contrivance, in fact, of the nature of a bird cage. This should be well connected at various points to earth, as nearly all buildings have gas and water-pipes and other metallic conductors in their interiors which are likewise earthed. For structures intended for the manufacture or storage of gunpowder and other explosives, the adoption of this bird-cage protection would be justified on the score alone of public safety. Architectural considerations prevent the adoption of such a method in its entirety for ordinary buildings; there is no doubt, however, that practically perfect protection may be assured by a judicious modification of the existing practice of erecting single lightning rods, especially in the case of extensive and lofty buildings that project well above surrounding structures, or that stand isolated in the open country.

"It is obvious that the extent to which the building should be protected, and the expense to be incurred in this protection, must bear some definite relation to the importance or cost of the building itself. In cases where protection is considered desirable, but heavy expense is not justified, two or more lightning rods might be erected in the ordinary manner, these being connected by a horizontal conductor, and the metal portions of the roof and the rain-water down pipes should be metallically connected and well earthed.

"Tall chimney shafts are not efficiently protected against a B flash by an ordinary single lightning rod, as a hot column of smoke issuing from a chimney

conducts as well as, or even better than a rod. A circular band should surround the top of the shaft; four or more conductors should be raised above the latter in the form of a coronal, or the Continental practice of joining the elevation rods together, so as to form an arch over the chimney, may be employed with advantage. One, or preferably two, lightning rods should extend from this circular band to the earth in the manner described below.

"As most buildings contain systems of gas and water pipes, a good earth for the lightning conductors is highly desirable. In the case of a stove inside a building with a metallic stove pipe carried outside, the stove should be earthed, and a wire be led from the pipe to the earth outside, or to the nearest conductor.

"The various cases noted by the Committee show that, while even single conductors tend to diminish the damage done to buildings by lightning, no reliance can be placed on an area of protection. In churches and other buildings with spires and towers, the lower projections should also be protected, if forming part of the salient features of the building."

It is gratifying to learn that "in the opinion of the Committee the methods advocated in the *Report of the Lightning Rod Conference* still hold good, provided arrangements are made to keep the earth permanently moist." The Committee have therefore deemed it convenient to reprint the rules issued by the Lightning Rod Conference in 1882, supplementing them with observations and suggestions of their own based on the results of their recent researches.

It may perhaps be desirable to recall the fact that the Lightning Rod Conference was formed in 1878 on the initiation of the Council of the [Royal] Meteorological Society, and consisted of delegates from that Society and also from the Royal Institute of British Architects, the Society of Telegraph Engineers and of Electricians, and the Physical Society, as well as two co-opted members. Mr. G. J. Symons, F.R.S., was the Secretary of the Conference, and was the editor of the *Report* (290 pp.), which was published in 1882.

The Lightning Research Committee conclude their Report by stating that their investigations warrant them in putting forward the following practical suggestions:—

1. Two main lightning rods, one on each side, should be provided, extending from the top of each tower, spire, or high chimney stack by the most direct course to earth.
2. Horizontal conductors should connect all the vertical rods (*a*) along the ridge, or any other suitable position on the roof; (*b*) at or near the ground line.
3. The upper horizontal conductor should be fitted with aigrettes or points at intervals of 20 or 30 feet.
4. Short vertical rods should be erected along minor pinnacles, and connected with the upper horizontal conductor.
5. All roof metals, such as finials, ridging, rain-water and ventilating pipes, metal cowls, lead flashing, gutters, etc., should be connected to the horizontal conductors.
6. All large masses of metal in the building should be connected to earth either directly or by means of the lower horizontal conductor.
7. Where roofs are partially or wholly metal-lined, they should be connected to earth by means of vertical rods at several points.
8. Gas pipes should be kept as far away as possible from the positions occupied by lightning conductors, and as an additional protection, the service mains to the gas meter should be metallically connected with house services leading from the meter.

Observations during the Solar Eclipse, August 30, 1905.

We have received the following special observations, which were made during the solar eclipse on Wednesday, August 30, 1905:—

STOKESAY, SHROPSHIRE.—Observer, Rev. W. M. D. LA TOUCHE.

	Dry.	Wet.	Max.	Min.	Max. in Sun.	Grass Min.
	°	°	°	°	°	°
9.0 a.m.	57·0	53·0	...	...	...	...
10.0 ,,	57·0	53·0	58·0	48·7	71·2	40·5
11.0 ,,	58·3	53·2	61·7	...	115·3	59·0
Noon	59·0	53·2	60·8	58·3	104·1	59·0
12.30 p.m.	58·9	53·7	59·9	58·5	104·7	61·2
1.0 ,,	56·9	52·8	59·1	56·7	74·4	56·1
1.30 ,,	56·6	53·0	57·1	56·2	61·6	55·9
2.0 ,,	56·5	52·7	57·2	56·1	64·0	57·0
3.30 ,,	57·3	54·1	58·3	56·3	67·7	58·0
5.0 ,,	56·4	52·5	58·5	56·3	75·5	56·9

BELMONT, HEREFORD.—Observer, Rev. H. DE NORMANVILLE, O.S.B.

	Dry Bulb.	Black Bulb in Vac.
11.45 a.m.	60·0	92·3 (cloudy)
Noon	60·9	104·9
12.15 p.m.	61·7	108·5
12.30 ,,	59·0	74·8 (cloudy)
12.45 ,,	57·5	Observations discontinued on account of clouds.
1.0 ,,	56·8	
1.50 ,,	59·0	
1.55 ,,	59·2	
5.0 ,,	58·0	

Remarks.—Sky overcast from 12.30 to 1 p.m.

Intermittent glimpses of eclipse caught from 1 p.m. (when principal phase was seen) till 2 p.m.

Temperature rose after eclipse in spite of cloudiness.

Wind, N.N.E., observed to fall just before middle of eclipse.

Observations on light power doubtful owing to clouds, but slight diminution noticed about 12.10 when sun was shining.

GUERNSEY.—Observer, A. COLLENETTE.

Hour.	Barometer Corrected.	Dry Bulb.	Solar Radiation Thermometer.	Wind.	Cloud.	Face of Sun.	Type of Cloud and Position.
a.m.	ins.	°	°				
9·0	29·759	59·2	...	WNW	8	...	Cumulo-stratus.
11·40	29·825	61·4	123·0	NNW	1	Clear	Stratus in W.
11·50	29·825	60·8	121·8	NNW	2	,,	,, ,,
Noon	29·824	60·2	120·2	NNW	1	,,	,, ,,
p.m.							
12·10	29·824	60·0	115·9	N	2	,,	Cirrus in SW.
12·20	29·827	59·7	108·8	NW	2	,,	,, ,,
12·30	29·827	59·5	102·8	NNW	3	,,	,, ,,
12·40	29·845	58·7	100·1	NNW	2	,,	Cirrus in SW. and zenith.
12·50	29·843	58·5	98·9	NNW	1	,,	Cirrus in SW.
1·0	29·857	57·6	71·2	NW	1	,,	,, ,,
1·10	29·857	57·4	71·5	NNW	2	Observed for 6 mins. 1.10–1.16	Stratus in WNW. and over sun.
1·20	29·857	57·6	90·0	NNW	1	Clear	Stratus over sun and near.
1·30	29·859	58·5	88·2	NW	0	,,	Stratus in S.
1·40	29·849	59·5	104·4	NNW	0	,,	Blue sky with haze.
1·50	29·862	60·4	124·2	NNW	0	,,	,, ,,
2·0	29·861	61·0	119·5	NNW	0	,,	,, ,,
2·20	29·860	61·4	127·4	NW	1	,,	,, ,,
9·0	29·989	52·5	...	NW	0	...	,, ,,

LINCOLN.—Observer, W. MARRIOTT.

I was in Lincoln on this day and saw a good deal of the eclipse through the breaks in the clouds. The sun could be comfortably looked at through the thin clouds without the aid of smoked glass.

There was a great diminution in the daylight some time before the maximum phase, and an increase in the daylight afterwards. The swallows in the neighbourhood of the Cathedral about a quarter of an hour before the maximum phase seemed much agitated, and began to fly low and round the trees as if going to roost. About a quarter of an hour after the maximum the swallows seemed to have recovered and were flying higher.

Exploration of the Atmosphere in the Tropics.

In *Nature* of July 13 (p. 244) there appeared a letter by Mr. Rotch, director of the Blue Hill Meteorological Observatory, U.S.A., describing the Franco-American expedition for the exploration of the atmosphere in the tropics, which was sailing on M. Teisserenc de Bort's steam yacht *Otaria*. During a two months' cruise the scientific members of the expedition, Messrs. Maurice, of Trappes Observatory, and Clayton, of Blue Hill, executed thirty-two soundings with balloons and kites, and made observations on two tropical peaks, all between latitudes 9° and 37° N. and longitudes 16° and 31° W. A Southerly or South-westerly return Trade was found at a height of about two miles in the tropics, and an Easterly wind in the equatorial regions, confirming the generally accepted theory of atmospheric circulation.—*Nature*, September 28, 1905.

Climate of the Cameroons.—The following Notes by Dr. PLEHN and H. HUTTER have been translated from the *Meteorologische Zeitschrift*, December 1904.

The whole coast and adjacent land is enclosed by the Cameroon Mountains, up to the level of about 2700 ft., and has a similar climate. The Meteorological Equator is to be put at 3° N. lat., and the greater part of the colony belongs to the northern hemisphere and only a little to the southern.

On the coast there is a decided tropical climate with constant damp heat and extraordinary rain. But, although it is near the equator, the climate is not very hot. This is partly due to the cold current, which flows along the coast of Africa as the Benguela current. The temperatures are not high, but yet the climate is unhealthy for Europeans, mainly owing to the excessive rainfall.

The mean annual temperature in the Cameroon estuary is 78°; on the southern foot of the Cameroon mountains, 77°; at Lokundje, in the south, 73°. The warmest month in the estuary, February, has 81°. The coolest, July, 76°. The mean maxima and minima lie between 90° and 66°.

One great feature of the climate is the frequency of thunderstorms. Hardly a day passes without an electrical explosion of some kind or other. In the rainy season actual thunderstorms are rare. It is different in the dry season in the change from rainy to dry weather, which is the tornado period. From one tornado there may be as much electrical activity as in three or four German thunderstorms. The frequency of the flashes may be gathered from the expression "lightning rain." If the counting of flashes is possible in slight thunderstorms, a strong tornado soon makes this impossible, and the observer recklessly abandons himself to watching the display of the uncurbed forces of nature. "I think there is nothing more magnificent than a tornado in the Cameroons" (Hutter).

Dr. Plehn gives the following account of the course of the seasons north of the equator :—

The turn of the year, January, is the highest point of the hot rainless time. The sun is quite concealed, on rising, by the uniform dark mist which then

overspreads the landscape. The vegetation is covered with heavy dew which soon disappears when the sun comes out, the land wind which has blown all night with a force of 3 [probably 6 Beaufort Scale] and upward, dies down and is not felt after 8 a.m. Then, with the sunshine begins the unsupportable time of Cameroon life. The cloudy grey mist? (Höhenrauch) (possibly due to grass-fires in interior?) over the river does not disappear with the sunshine, and the Cameroon mountain is covered for weeks with the thick cloud. Despite the relative reduction of humidity (73-76 per cent), the atmosphere at noon, with its temperature of 85° or so, is unbearably oppressive, especially at the time of low-water on the shore. About 1 o'clock the sea breeze sets in from South-west and with considerable force, giving some relief in spite of the heat. It also brings up plenty of clouds, which also moderate the intense heat of the sun. Rain seldom falls at this time, sometimes for 3 or 4 weeks. Nevertheless the vegetation shows no outward sign of the reduction of humidity. It is only by the great fall in the water level that one can trace the effect of the deficiency of rain.

There is often towards evening sheet lightning and distant thunder, though severe thunderstorms are very rare at this time. The sunsets and twilight phenomena are specially magnificent. As at sunrise, the red circle of the sun disappears at some height above the horizon behind the uniform grey mist which covers it. The nights are mostly cloudless; the moon is not unfrequently surrounded by a reddish yellow corona.

Not long after sunset the sea breeze ceases, and gives way to the Easterly land wind which holds on till morning.

It is only for a short time that the picture of the typical dry season is observed; for weeks before its appearance, and before its change into the spring tornado season, days of the described character alternate with others which have heavy clouds, apparently thunderstorm clouds, and sudden rains as well as occasional tornados, reproducing the special character of the so-called transition state, the tornado time.

The first of these special storm phenomena of the tropics appear in small numbers; in March and April they are more common and stronger. Sheet lightning and constant thunder in the east increase, and regular rainy days among the warm sunny ones are more and more frequent.

It is exactly at this transition period, in which heavy spells of rain of short period alternate with intensive sunshine, that the hot hours of the day, in which the sun standing higher shines on the soil soaked by the rain, are specially oppressive.

The longer this transition state goes on the sunny days are fewer, and the rain takes on a more uniform character. The tornados are rarer and not so violent, and the electrical discharges less severe. The sunsets are mostly clear, and so are the nights unless darkened by rain clouds. The land breeze increases, the rain comes mostly from the sea. Thus the transition stage passes into the rainy season, which reaches its height between June and August. The face of the sun is rarely observed; the rain falls incessantly from the dark uniformly grey sky, at times less violent and at times more, at night heavier than by day.

Everything is enveloped in a dark watery grey veil. Puddles and pools are formed, small dry watercourses swell to raging torrents, brooks to rivers. The wind dies down, nevertheless, and despite the increase of humidity, the human body feels the lower night temperature, and the absence of the intense solar radiation is very nice, but the occasional appearance of the sun is far from pleasant, as it brings on fevers.

With intervals the rainy period lasts until the autumn. And now begins in reverse order the change to the dry season again, with the interval of

tornados. The vegetation at this time, when the solar action combines with the soaked soil, reaches its greatest development, as does also the fever mortality, which increases towards the beginning of the dry season. The heat on the warm forenoon is specially great, and the fevers are accompanied by the diseases of the dry season, increase of nervous action, and diseases of digestion and of the skin.

In this way, with gradual increase in the warm days and decrease of the severe fevers, the dry season sets in again in November.

RECENT PUBLICATIONS.

British Rainfall, 1904. *Forty-Fourth Annual Volume. On the Distribution of Rain over the British Isles during the year* 1904, *as observed at about* 4000 *Stations in Great Britain and Ireland, with Articles upon various Branches of Rainfall work.* Compiled by HUGH ROBERT MILL, D.Sc., LL.D., F.R.S.E. London, 1905. 8vo. 87 + 279 pp.

In his report Dr. Mill refers to the constitution and the function of the various bodies dealing with meteorology in this country, viz. the Meteorological Office, the Royal Meteorological Society, the Scottish Meteorological Society, and the British Rainfall Organization. The original articles are: (1) the Rainfall Observations on Ben Nevis; (2) Dry Octobers; and (3) on the Duration and Average Weight of Rainfall at Camden Square, London, 1881-1904. A welcome addition to this year's volume is the record of daily rainfall at ten representative stations.

Dr. Mill shows that the rainfall for 1904 was not on the whole remarkable, but it was nevertheless a dry year, which appeared the drier on account of the great contrast presented with the previous year, the wetness of which was almost unprecedented. The general distribution of rainfall in 1904 was to heighten the contrast between west and east, the normally wet west being wetter, and the normally dry east being much drier than in an average year. The dry area was much more extensive as well as more extreme than the wet area.

The rainfall of the British Isles was distributed as follows:—

England and Wales	30·25 ins.
Scotland	43·72 ins.
Ireland	40·67 ins.

There was thus a deficiency of 12 per cent over England and Wales and 4 per cent over Scotland, while over Ireland the rainfall was almost exactly the average.

Meteorology, or Weather Explained. By J. G. M'PHERSON, Ph.D., F.R.S.E. London, 1905. 8vo. 126 pp.

This is a chatty little book, but it hardly comes up to the expectation raised by the title-page. It is not a treatise on meteorology, but is largely a popularised account of the investigations of Mr. John Aitken, F.R.S., which have been described in papers published in the *Transactions of the Royal Society of Edinburgh.*

Twenty Years on Ben Nevis. Being a Brief Account of the Life, Work, and Experiences of the Observers at the highest Meteorological Station in the British Isles. By WM. T. KILGOUR. With illustrations. Paisley, 1905. 8vo. 154 pp.

This is a most interesting account of the life-story of those who, during the past two decades, have laboured in the interest of science on the summit of Ben

Nevis. The author states that he was intimately associated with the Observatory during the greater part of its existence, and that, though not a regular member of the meteorological staff, it was his pleasure occasionally to take up duty at the lofty station. Some idea of the scope of the book will be gathered from the titles of the eighteen chapters into which it is divided, viz.—Impressions; The Observatory; Work of the Observers; The Commissariat; Adventures; Records; Ceremonials on the Summit; Accidents; Phenomena; Storms; Prospect; Winter and Summer Pastimes; Extracts from the Visitors' Book; Some Entries from the Log; Fauna and Flora; Troubles—Physical and Otherwise; Mountaineers; and the Closing of the Observatory.

METEOROLOGICAL LITERATURE.

The following titles of papers bearing on Meteorology have been selected from the contents of some of the periodicals and serials which have been received in the Library of the Royal Meteorological Society. This is not a complete list of all the published meteorological articles, but only shows those that appear to be of general interest.

For a full Bibliography the reader is referred to the *International Catalogue of Scientific Literature.*

Angot, A.—Contribution à l'étude de la variation diurne de la température. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (174-176).

Bartlett, J. L.—The Influence of Small Lakes on Local Temperature Conditions. *Monthly Weather Rev., Washington,* **33**, 1905 (147-148).

Bauer, L. A.—Work of the Department of Terrestrial Magnetism of the Carnegie Institution for 1905. *Terrestrial Magnetism, Baltimore,* **10**, 1905 (103-105).

Besson, L.—L'ascension scientifique du 5 avril 1905. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (124-130).

Bigelow, F. H.—Studies on the Diurnal Periods in the Lower Strata of the Atmosphere:—I. The Diurnal Periods of the Temperature. *Monthly Weather Rev., Washington,* **33**, 1905 (52-55).—II. The Diurnal Periods of the Barometric Pressure. *Monthly Weather Rev., Washington,* **33**, 1905 (93-97).—III. The Diurnal Periods of the Vapour Tension, the Electric Potential and Coefficient of Dissipation. *Monthly Weather Rev., Washington,* **33**, 1905 (132-137).

Bigelow, F. H.—Application of Mathematics in Meteorology. *Monthly Weather Rev., Washington,* **33**, 1905 (90-92).

Bigelow, F. H.—The Observations with Kites at the Blue Hill Observatory, 1897-1902. *Monthly Weather Rev., Washington,* **33**, 1905 (137-138).

Bodman, G.—Meteorologische Ergebnisse der Schwedischen Südpolar-Expeditionen. *Meteor. Zeits., Vienna,* **22**, 1905 (313-319).

Bonacina, L. C. W.—The Study of Thunderstorms. *Symons' Met. Mag., London,* **40**, 1905 (118-119).

Börnstein, R.—Der tägliche Gang des Luftdruckes in Berlin. *Meteor. Zeits., Vienna,* **22**, 1905 (299-305).

Busch, F.—Beobachtungen über die Wanderung der neutralen Punkte von Babinet und Arago während der atmosphärisch-optischen Störung der Jahre 1903 und 1904. *Meteor. Zeits., Vienna,* **22**, 1905 (248-254).

Cooke, W. E.—Islands for Weather Forecasting Purposes. *Nature, London,* **72**, 1905 (343-344).

Curtis, R. H.—On the Amount of Heat required for the Growth and Ripening of Wheat. *Symons' Met. Mag., London,* **40**, 1905 (113-116).

Durand-Greville, E.—Quelques progrès possibles en météorologie. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (169-174).

Eiffel, G.—Analyse de l'ouvrage, études pratiques de météorologie, et observations comparées des stations de Beaulieu, Sèvres et Vacquey pour l'année 1903. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (148-155 and pl.).

Fényi, J.—Über Temperatur-Erniedrigung infolge erhöhter Insolation. *Meteor. Zeits., Vienna,* **22**, 1905 (311-313).

Field, Capt. A. M.—Report on an Area of Local Magnetic Disturbance in East Loch Roag, Lewis, Hebrides. *Proc. Roy. Soc., London,* A, **76**, 1905 (181-184).

Gerdien, H.—Die absolute Messung der specifischen Leitfähigkeit und der Dichte des verticalen Leitungsstromes in der Atmosphäre. *Terrestrial Magnetism, Baltimore,* **10**, 1905 (65-79).

Hegyfoky, J.—Die tägliche Drehung der Windrichtung. *Wetter, Berlin,* **22**, 1905 (121-128).

Henry, A. J.—High Water in the Great Lakes. *Monthly Weather Rev., Washington,* **33**, 1905 (47-49).

Hopkinson, J.—Report on the Rainfall in Hertfordshire in the year 1903. *Trans. Herts. Nat. Hist. Soc., London,* **12**, 1904 (97-108).

Hopkinson, J.—Meteorological Observations taken in Hertfordshire in the year 1903. *Trans. Herts. Nat. Hist. Soc., London,* **12**, 1904 (117-124).

Jones, J. R. G.—Glacial Snow on Ben Nevis. *Symons' Met. Mag., London,* **40**, 1905 (83-84).

Kerner, F. von.—Zur Kenntnis der Temperatur der Alpenbäche. *Meteor. Zeits., Vienna,* **22**, 1905 (241-248).

Kimball, H. H.—The Variations in Atmospheric Transparency during 1902, 1903, and 1904. *Monthly Weather Rev., Washington,* **33**, 1905 (100-101).

Kremser, V.—Sonnenlose Tage. *Wetter, Berlin,* **22**, 1905 (97-103).

Langbeck, R.—Die Gewitter am 6. und 7. Juni 1905. *Wetter, Berlin,* **22**, 1905 (145-151).

Launay, F., et Maillet, E.—Sur le débit probable des sources pendant la saison chaude de 1905 (1er mai-1er novembre). *Ann. Soc. Mét. France, Paris,* **53**, 1905 (145-147).

Leitch, D. L.—Duration and Area of Heavy Rainfalls. *Rep. S. African Assoc., Johannesburg,* **1904** (380-382).

Lockyer, W. J. S.—Islands for Weather Forecasting Purposes. *Nature, London,* **72**, 1905 (111-112).

Lockyer, W. J. S.—Solar Changes and Weather. *Nature, London,* **72**, 1905 (129).

Lockyer, W. J. S.—The Thames Flow and British Pressure and Rainfall Changes. *Nature, London,* **72**, 1905 (178-180).

M'Leod, C.—Records of Difference of Temperature between M'Gill College Observatory and the Top of Mount Royal, Montreal. *Proc. Roy. Soc., London,* A, **76**, 1905 (415-418).

M'Lure, H.—The Climatology of the Sahara. *J. of Balneology and Climatology, London,* **9**, 1905 (163-172).

Maillett, E.—Sur la classification des sources servant à l'alimentation des villes en France et en Algérie. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (113-117).

Marchand, E.—Twilight Glows and Connected Phenomena observed in 1902, 1903, and 1904 in the Pyrenees. Translated from *Ann. Soc. Mét. France,* **53**, 1905 (40-45), by Miss R. A. Edwards. *Monthly Weather Rev., Washington,* **33**, 1905 (101-103).

Maunder, E. W.—Magnetic Disturbances as recorded at the Royal Observatory, Greenwich, and their association with Sun-spots. Third Paper. *Mon. Not. R. Astr. Soc., London,* **65**, 1905 (666-681).

Maurer, J.—Zur Geschichte der terrestrischen Refraktion. *Meteor. Zeits., Vienna,* **22**, 1905 (262-265).

[Mill, H. R.]—The Rainfall and Weather of May 1905. *Symons' Met. Mag., London,* **40**, 1905 (77-80).

Mitchell, A. J.—Wind Velocities for different Altitudes and Exposures. *Monthly Weather Rev., Washington,* **33**, 1905 (153).

Mossman, R. C.—The Antarctic Meteorological Station in the South Orkneys. *Symons' Met. Mag., London,* **40**, 1905 (86-89).

Mossman, R. C.—Some Results of the Scottish National Antarctic Expedition. 4. Meteorology. *Scot. Geog. Mag., Edinburgh,* **21**, 1905 (417-429).

Moureaux, T.—Résumé de trente années d'observations météorologiques à l'observatoire du Parc Saint-Maur (1874-1903). V.—Humidité relative. *Ann. Soc. Mét. France, Paris,* **53**, 1905 (118-124).

Nimführ, R.—Sehr tiefe Temperaturen in grossen Höhen der Atmosphäre. *Meteor. Zeits., Vienna,* **22**, 1905 (289-299).

Okada, T.—Discussion of the Earth Temperature Observations made at Osaka Meteorological Observatory. *J. Met. Soc. Japan, Tokio,* **24**, 1905, No. 3.

Quervain, A. de.—Aus dem Leben der Wolken. *Wetter, Berlin,* **22**, 1905 (129-137).

Reid, H. F.—Records of Seismographs in North America and the Hawaiian Islands. *Terrestrial Magnetism, Baltimore,* **10**, 1905 (81-96).

Rotch, A. L.—The First Observations with "Ballons-Sonde" in America. *Aëronautical Journal, London,* **9**, 1905 (51).

Schubert, J.—Die Witterung in Eberswalde im Jahre 1904. *Wetter, Berlin,* **22**, 1905 (151-158).

Shaw, W. N.—Seasons in the British Isles from 1878. *J. Roy. Stat. Soc., London,* **68**, 1905 (247-313).

Sieberg, A.—Erdbeben und Witterung. *Wetter, Berlin,* **22**, 1905 (103-113).

Solar and Terrestrial Changes. *Nature, London,* **72**, 1905 (249-250), (332-333).

Some Aspects of Modern Weather Forecasting. *Nature, London,* **72**, 1905 (354-355).

Staikof, St. D.—Dämmerungs-Erscheinungen der Jahre 1903-1905 in Sofia, Bulgarien. *Wetter, Berlin,* **22**, 1905 (159-161).

Stentzel, A.—Dämmerungs-Störungen. *Wetter, Berlin,* **22**, 1905 (115-117).

Stewart, C. M.—The Blizzard of June 9-12, 1902 [in South Africa]. *Rep. S. African Assoc., Johannesburg,* **1904** (118-120 and 2 pl.).

Sutton, J. R.—Results of some further Observations upon the Rate of Evaporation. *Rep. S. African Assoc., Johannesburg,* **1904** (121-141).

Tallquist, H.—Karl Selim Lemström; His Life and Work. *Terrestrial Magnetism, Baltimore,* **10**, 1905 (97-100).

Tamura, S. T.—Mathematical Theory of Ice Formation. *Monthly Weather Rev., Washington,* **33**, 1905 (55-59).

Tamura, S. T.—Mathematical Theory of the Nocturnal Cooling of the Atmosphere. *Monthly Weather Rev., Washington,* **33**, 1905 (138-147).

Teisserenc de Bort, L.—Die Erforschung der Passat-region des Nordatlantischen Ozeans. *Meteor. Zeits., Vienna,* **22**, 1905 (330-332).

The Antarctic Problem. *Scot. Geog. Mag., Edinburgh,* **21**, 1905 (376-378).

Über die Regen-Verteilung in Niederösterreich. *Meteor. Zeits., Vienna,* **22**, 1905 (306-310).

Wegener, A.—Blitzschlag in einen Drachenaufstiege am königlichen aeronautischen Observatorium, Lindenberg. *Wetter, Berlin,* **22**, 1905 (165-167).

Wilms, L.—Lightning Arresters for Electric Transmission Lines. *Rep. S. African Assoc., Johannesburg,* **1904** (455-468 and pl.).

Wundt, W.—Temperaturen auf Bergstationen und in der freien Atmosphäre. *Wetter, Berlin,* **22**, 1905 (138-142).

INDEX.

THE END OF VOLUME XXXI.

Printed by R. & R. Clark, Limited, *Edinburgh*